



**NOAA TECHNICAL MEMORANDUM
NMFS-SEFC-221**

**STOCK ASSESSMENT FOR BROWN, WHITE
AND PINK SHRIMP IN THE U.S.
GULF OF MEXICO, 1960 - 1987**

BY

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INTRODUCTION

The need to better manage the penaeid shrimp stocks of the United States, to insure that all involved in the fishery may benefit from this common resource, has prompted this research effort. This stock assessment report deals only with the 1960-1987 commercial catch statistics for brown shrimp (Penaeus aztecus), white shrimp (Penaeus setiferus) and pink shrimp (Penaeus duorarum) from the U.S. Gulf of Mexico shrimp fishery. This analysis provides the annual update of the status of the shrimp stocks presented at the Southeast Fisheries Center's Second Stock Assessment Workshop (Nichols, 1984).

METHODS

The same procedures explained at length by Nichols (1984) were used in this stock update analysis. The brief synopsis of the methods presented below was taken from the last stock assessment report by Nichols (1986). Only minor changes were made to some statements.

Single stocks of brown and white shrimp throughout their ranges in the Gulf of Mexico were assumed. A single pink shrimp stock from the Florida Keys to the Mississippi River was assumed. Brown shrimp landings reported in Texas included an unknown

quantity of pink shrimp, which was treated as brown shrimp for this analysis. No detailed information was available for shrimp caught and landed in Mexico, so the analyses were conducted as if the ranges of brown and white shrimp stocks ended at the Mexican border.

Computerized 1987 data files for the shrimp landings and effort interviews in the U.S. Gulf of Mexico were obtained from the Economics and Statistics Office, Southeast Fisheries Center. These data were subjected to the additional editing criteria developed by the Fisheries Analysis Division, Miami Laboratory, as described by Nichols (1984). These edited data were combined with the previously edited 1960-1986 data set for the updated analysis. Estimates of species-directed effort were calculated by the same procedures used by Nichols (1984).

No time series data were available for catches not reported through the commercial channels covered by the dealer canvassing program. Although these catches may be sizeable, they could not be included in the present analysis. Absence of estimates for unreported catches is probably the greatest potential source of error in this work.

The von Bertalanffy growth curves developed by Parrack (1981) were used as the age-length relationship for brown shrimp. The white shrimp analysis used the seasonally varying growth

model developed by Nichols (1981), while growth curves derived by Phares (1981, unpublished) were used for pink shrimp (parameters tabled in Nichols 1984). Necessary length-weight conversions were made using factors reported by Brunenmeister (1980), Parrack (1981), Phares (1980), and Phares (1981, unpublished). Modifications to t_0 parameters, procedures to estimate ages of the sexually dimorphic brown and pink shrimp from size data without sex, details of the catch in weight to catch in numbers by age transformation, and adjustments to the growth relationships for calculating realized yield per recruit remained as described by Nichols (1984).

A natural mortality rate (M) of 0.275 per month for both brown and white shrimp, and 0.3 per month for pink shrimp was used in the present study. Sensitivity was investigated using M = 0.2 and 0.35 per month for all three species.

Age specific estimates of fishing mortality rates (F) and stock sizes (N) were made using virtual population analysis. For cohorts considered extinct by December 1987, starting F for the oldest age considered was estimated as

$$F = qf$$

where q took the value associated with each estimate of M (Table 1), and f was the directed effort for that month. For cohorts

extant in December 1987, age specific estimates of q were calculated as the averages of the F/f ratios for all Decembers preceding 1987. The starting F was then calculated as the product of each q estimate and fishing effort for December 1987. The detailed tables of age specific stock sizes and fishing mortality rates are available from the author.

The evaluation of possible stock-recruitment relationships conducted by Nichols (1984) was repeated. The Beverton-Holt stock recruitment model was assumed, reparameterized as:

$$R = \frac{P \times R_{MAX}}{P + S}$$

where R_{MAX} is the maximum asymptotic recruitment, S a half-saturation parameter, P the parent stock size in numbers, and R the annual recruitment in numbers (semi-annual for pink shrimp). The best way of indexing parent stock is unknown, so an array of possible parent stock size indices was considered, varying the minimum age considered and the month used. For rapid evaluation, the stock recruitment parameters were estimated using a linearized form

$$\frac{P}{R} = \frac{P}{R_{MAX}} + \frac{S}{R_{MAX}}$$

via simple regression. Parameters were estimated for each month/minimum age combination, "goodness" was evaluated with R^2 , and those combinations showing good fits were examined further. From these, two cases for each species were selected for presentation. In general, none of the cases considered are very convincing as cause/effect relationships. The particular cases chosen for presentation merely demonstrate 1) the type of relationships seen and 2) the sensitivity of conclusions about the state of the fishery with respect to recruitment overfishing.

As in Nichols (1984, 1985), deterministic population models were produced for all three species by linking a Ricker-type yield per recruit model to proposed stock recruitment relationships. In addition to the stock recruitment models just described, recruitment independent of parent stock was also considered, with recruitment set at the geometric mean over the 1960-1987 period. Averages of VPA-derived F estimates for 1985-87 were used as the baseline for "current conditions". Yield estimates were made for all three species for a range of possible season openings (monthly increments) and for a range of "F-multiplier" values from 0-2 (0.02 increments). These tables of yield estimates were searched for maxima. The pink shrimp models were slightly more complicated because two 6 month seasons of stock-recruitment relationships were considered, but the general idea is the same.

RESULTS

Brown Shrimp

Landings of brown shrimp have exhibited a rising trend for the past 28 years, with minor short term fluctuations (Fig. 1). Lowest values occurred in the early 1960's with around 30 million pounds of tails landed, while greatest values, at nearly 100 million pounds of tails landed, occurred in both 1981 and 1986. This 70 million pound increase in tails landed over the past 28 years has coincided with a more than doubling of the directed effort during the same period (Fig. 2). The rise in directed effort has been quite steady with the majority of fluctuations occurring during the 1970's. Effort during 1987 was the greatest ever experienced in the fishery with over 2 million days fished. With both landings and directed effort increasing, catch per unit effort (CPUE) has remained without an apparent trend and has shown a great deal of fluctuation around an annual mean of about 670 pounds per day (Fig. 3). Yet, with the tremendous increase in effort in the fishery, CPUE may start to experience a downward trend. The 450 pounds/day in 1987 was the lowest ever recorded in the past 28 years. The average size of brown shrimp landed during the 28 year period discussed in this paper has been on the decline (Fig. 4). Average size in 1960 was 48 count (count meaning number of shrimp tails per pound), while average size in 1987 was 81 count. However, for the past six years (1982-1987) the trend seems to have stabilized, with an average count of

around 80 shrimp per pound experienced during the period. The increase in pounds landed during the 1960-1987 period has come at the expense of a great many more brown shrimp than would have been required if the count size had remained at its 1960 value.

Annual recruitment has generally been increasing (Fig. 5). Though there has been considerable fluctuation, recruitment has increased from around 5 billion in the early 1960's to around 10 billion during the early 1980's. The increase in recruitment has slowed somewhat over the past three years and may have reached its peak at around 14 billion shrimp. It is this two-fold increase in recruitment that has allowed average CPUE to remain at a near level state, even with the increase in directed effort. If recruitment has indeed leveled off, any increase in effort above present levels will cause CPUE to drop, and recruitment over fishing may begin to occur. The percentage of recruits captured in a given year has increased to such a point that this value has been over 50% since 1978 (Fig. 6). However, yield per recruit has shown a near level trend with only very minor fluctuations occurring after 1972 (Fig. 7).

The parent stocks selected for presentation were November with a minimum age of 7 months and February with a minimum age of 6 months. Both parent stock size indices showed a slight decline from the mid-1960's to the mid-1980's, with increases during the late 1980's. Both stocks showed decreases in 1987 when compared

to 1986 (Figs. 8 and 9).

Recruitment versus parent stock plots show that in neither case is a relationship apparent (Figs. 10 and 11). However, because a recruitment-stock relationship must ultimately pass through the origin, relationships can be fitted and incorporate whatever curvature that exists in the data. Each curve is shown with replacement lines at zero exploitation and at the maximum surplus recruitment level. Both curves indicate that exploitation is just now reaching the maximum surplus recruitment level.

If a recruitment independent of parent stock relationship is assumed, then no further gain in yield will occur with an increase in fishing effort (current $F = 1.00$) under the existing seasonal fishing pattern (Fig. 12). The potential does exist for increasing yield by delaying fishing on new recruits. A July opening in the fishery would produce a 10.8 million pound benefit (14% increase) at current fishing levels. It should be noted that the benefit would not increase much further if fishing effort also increased. The maximum sustainable yield under this recruitment-stock relationship would be about 88 million pounds.

Under the November based recruitment-parent stock relationship, yields are almost at the maximum level for the current seasonal fishing pattern with the present level of fishing (Fig. 13). If all fishing were delayed until July a 15 million pound

benefit (21% increase) would be realized at current fishing effort levels. The maximum sustainable yield estimated with this recruitment-parent stock relationship is 79 million pounds, but effort must increase by 50% and fishing delayed until August to attain this yield.

Using the recruitment patterns based on a February parent stock, a maximum yield would be attained with the current season fishing pattern if effort was reduced by 20% (Fig. 14). Presently yield is at a level of 58 million pounds which is 3% below maximum. At the current fishing level, a 13 million pound increase (19% increase) is predicted if fishing were delayed until July. If fishing were delayed until August, a maximum sustainable yield of 75 million pounds is possible, if fishing efforts were about 50% greater than their current intensity.

White Shrimp

White shrimp landings exhibited a cyclic format without trend until the mid-1970's. Since that time the trend has still been quite cyclic, but with a distinct upward tendency (Fig. 15). Levels fell during the 1987 season. Directed effort has shown a more stable constant increase over the past 28 years (Fig. 16). Effort has increased from around 40 thousand fishing days in the early 1960's to record highs of nearly 170 thousand fishing days in 1986 and 190 thousand fishing days in 1987 (an increase of over 400%). This steady increase in effort, coupled with only a

slight increase in landings has resulted in a cyclic, but descending trend in overall CPUE values (Fig. 17). The average CPUE value in 1987 was only 284 pounds per day. During this same 28 year period, the average size of white shrimp landed has also decreased (Fig. 18). Count has gone from around 45 tails per pound in the early 1960's to about 70 tails per pound in 1987.

Annual recruitment of white shrimp has fluctuated greatly, but until this year has shown an overall upward trend (Fig. 19). Recruitment had increased from around 3 billion young in the early 1960's to almost 15 billion in 1986. Levels in 1987 decreased to around 8 billion shrimp. This is the largest decrease noted for a single year during the entire 28 year data base. It was the increase in recruitment that had allowed the CPUE values prior to 1987 to drop only slightly with the 4-fold increase in fishing effort. Thus, with the decrease in recruitment in 1987, the large effort levels caused CPUE to drop to an all time low level. The percentage of recruits captured has fluctuated at around the 30% level for many years (Fig. 20). However, the 1987 value increased to 47% captured. Yield per recruit has shown a slight decline with only very minor fluctuations (Fig. 21).

The two parent stock examples that were selected for analysis were April and August, both with a minimum age of 5 months. The April parent stock showed great fluctuations in abundance in

the early years (1960-1973), but only minor changes thereafter (Fig. 22). An increase has been observed for the past 3 years, with the 1987 value being the greatest ever experienced. August parent stocks have had tremendous fluctuations over the years (Fig. 23). There had been an increase in recent years, but a drop in stock occurred during 1987. The trend is similar to one experienced in the early 1960's. Only next year's analysis will determine if this downward trend will continue.

Existence of a stock-recruitment relationship seems apparent in plots of recruitment versus parent stock for both parental indices (Figs. 24 and 25), but it should be remembered that the minimum points on the plots occurred early in the data history, with effort at 1/4 to 1/2 recent levels. Thus, as pointed out by Nichols (1985), variation in stock and recruitment not directly associated with fishing may be important in establishing the form of the curve. The April parent stock index relationship suggests that exploitation has remained near the maximum surplus recruitment level for the past 28 years. The August parent stock index relationship shows that exploitation has been above the maximum surplus recruitment level for most of the period.

Yield models based on the VPA results were utilized to predict potential yield in a variety of situations. If a recruitment independent of parent stock relationship is assumed then a yield of 36 million pounds is expected with current fishing

patterns and at current effort levels ($F = 1.0$) (Fig. 26). The yield could be increased to a little above 38 million pounds (5% increase) by delaying fishing for four months (until October) and then fishing at the current effort level. A maximum sustainable yield of 41 million pounds could be reached if fished were delayed until October and then allowed at twice the current level.

Under the April based parent stock-recruitment relationship a yield of 34 million pounds is predicted with current fishing patterns and at current effort levels (Fig. 27). By decreasing effort by 54% of the present levels, an increase in yield of 8 million pounds (19% increase) could be obtained. This yield represents the maximum sustainable yield for the data set. If effort were kept at the same present level ($F = 1.0$), but delayed until November, a yield of 39 million pounds (13% increase) is expected. Both curves experience greatest yield at effort levels below the current rate.

Using the August based parent stock-recruitment relationship, a yield of 33 million pounds is expected at current effort levels with current fishing patterns (Fig. 28). If effort were reduced by 60%, an increase of 22 million pounds (40% increase) could be achieved. If effort was maintained at current levels, but fishing was delayed until October, an increase in yield of 42% (24 million pounds) over current values could be expected. This could be increased to 61 million pounds with the same delay

in fishing and a reduction in effort of 30%.

Pink Shrimp

Compared to the other two shrimp stocks discussed, the pink shrimp stock has remained quite stable over the past 27 years. Landings have fluctuated only slightly, without a clear trend (Fig. 29). Yet a decrease in landings was noted for 1986. Directed effort appears to have gone through a transition in about 1972 with a mean of 21 thousand days before the change and 26 thousand days afterward (Fig. 30). Effort values have remained quite stable on each side of this transition zone. CPUE has fluctuated with no clear trend around a mean of 568 pounds per day (Fig. 31). A notable decrease in CPUE occurred in 1986, when the average dropped to 374 pounds per day. Average size of shrimp captured has also shown considerable vacillation with no long-term trend over the past 27 years (Fig. 32). The average has been around 51 tails per pound during the period.

Annual recruitment has fluctuated throughout the 27 year period, but with greater oscillations occurring following 1970 (Fig. 33). A reduction in recruitment has been observed during the last two years. Realized yield per recruit values hardly varied through the 1960's and 1970's, but started to decline in the 1980's (Fig. 34). The yield per recruit value for 1985 put an apparent upward turn towards the mean in the data set, but the 1986 value did not continue the upward trend. Percentage of

recruits captured has shown great fluctuations over the years, with a slight downward trend apparent in the early years and until recently a slight upward trend was visible in later years (Fig. 35).

Pink shrimp recruitment-stock relationships showed best fits with January and July parent stocks, both with minimum age at 5 months. July parent stocks have shown an increasing trend over the past 27 years with a great increase in 1985, but back down to normal levels in 1986 (Fig. 36). January parent stocks have also shown a great increase in recent years, but no trend was apparent in early years (Fig. 37). A noticeable decrease occurred this last season.

Both spring and fall recruitments show little dependence on parent stock size, but models were fit to try and capture any curvature that exists in the data (Figs. 38 and 39).

Using a population model that assumes a recruitment that is independent of the parent stock, a yield of 12 million pounds can be expected with current fishing patterns at current fishing levels (Fig. 40). An 80% increase in effort would only increase yield to a maximum of 12.7 million pounds (6% increase). Delaying fishing for 2 months after recruitment and then fishing at current effort levels would also result in an increase in yield, but only about 0.7 million pounds (6% increase). Maximum sus-

tainable yield is attained by a delay' in fishing of 2 months after recruitment and then allowing fishing at twice the normal rate.

If a January and July parent stock-recruitment relationship is assumed, then a yield of 12.7 million pounds is expected with current fishing patterns and at current fishing levels (Fig. 41). A 6% increase in yield (from 12.7 to 13.5 million pounds) is predicted if current fishing effort is delayed for 2 months after recruitment. A maximum sustainable yield of 14.5 million pounds is expected if fishing is delayed 3 months after recruitment and then allowed at twice the normal rate.

DISCUSSION

Brown Shrimp

As in earlier reports (Nichols 1984, 1985) the most important result for brown shrimp is the upward trend in recruitment over the past 28 years. Regression analysis on the data gave an r^2 value of .56 with a slope of .24. Since there was virtually no trend in either CPUE or yield per recruit, despite a 2-fold increase in directed effort, the increase in landings appears to be directly attributable to the increase in recruitment and not to the increase in effort. However, if effort continues to rise unchecked, noticeable decreases in CPUE may begin to occur.

Nichols (1984) conducted extensive sensitivity trails with the brown shrimp data and failed to find any plausible set of input parameters that removed the recruitment trend. Nichols and Cummings (1984) on examination of CPUE on the smallest sizes of shrimp also detected an upward trend in recruitment. Thus, the increase in recruitment appears not to be just an analytical artifact.

An increased percentage of the recruits are captured each year. However, this does not mean a reduction in parent stock the next year as has been seen (Fig. 8 and 9). The increase in available recruits has allowed more to be taken without causing a drop in parent stocks. Recruits are not only being captured in larger numbers, but also at an early age. Average age of capture in 1960 was 2 months, while in 1987 it was 1 month. The average size of shrimp landed has also declined steadily over the historical period.

The evidence of any stock-recruitment relationship for brown shrimp remains unpersuasive. Attempting to fit the data to a single stock-recruitment curve ignores the existence of the temporal trends and treats the deviations from the line as if they are random and independent (Nichols 1986). Any conclusions based on these models must be used with caution. Both curves examined show that recruitment overfishing of shrimp populations probably has not yet occurred. Both curves indicate that current

fishing is now just reaching the maximum surplus recruitment level.

Yield curves provide us with choices about how to best manage the fishery and obtain a better yield. Although the different scenarios remained firm in predicting increasing or decreasing yields when different natural mortality rates are used ($M = .2 - .35$), the percentage gained or lost was greatly affected with the choice of M . Nichols (1986) points out that the residual uncertainty about M still limits our ability to "fine tune" evaluations of any proposed management modifications. Trends can be determined and increases or decreases in yield predicted, but the percentage change in yield is still elusive. The larger the M is in the population, the less yield will be produced by delaying fishing and allowing shrimp to grow.

White Shrimp

Recruitment to the white shrimp fishery has also shown a general increase over the past 28 years. Regression analysis on the data produced as r^2 value of .42 and a slope of .22. Yet, major reduction occurred during the 1987 season. Both landings and directed effort have shown increases for white shrimp fishery. However, landings have increased to a much lesser extent in recent years and this has caused a decrease in average CPUE. These facts point to the possibility that recruitment over fishing maybe occurring in the white shrimp fishery.

Another trend which should be mentioned is the decrease in the average size of white shrimp caught. However, even with this observed downward trend in size, the percentage of the recruitment caught each year has remained quite stable, except for the large increase noted this year. Average age at time of capture has also remained at a fairly stable level with an average age of 2.95 months in 1960 and an average age of 2.75 months in 1987.

Stock-recruitment relationships do appear evident for white shrimp. Yet, the real nature of the relationship seems open to question. Lowest recruitment occurred early in the fishery when fishing effort was also low, while presently we have seen an increase in recruitment coupled with an increase in effort. If the increase in effort was simply in response to the increase in recruitment, then we should see a pattern of recruitment values moving from right to left in Figures 24 and 25 as their replacement lines shifted in a counter-clock-wise direction. This is clearly not the case. It appears from the data that the parent stock-recruitment relationship has changed over the years and what we are attempting to do is place one curve over a data set that should be represented by a number of different curves. However, other trends in the fishery strongly suggest that the curve may be real and that recruitment overfishing is occurring. With the major increases in effort noticed the last two years, and the sizable decrease in recruitment, the white shrimp fishery may be on the decline.

Pink Shrimp

As with previous reports (Nichols 1984, 1986), the most notable result for the pink shrimp stock is the stability of the fishery over the past 27 years, with the exception of the decrease in landings and recruitment this last year. Because of this lack in variation within the fishery, estimations of M and stock recruitment relationships are not as precise as those established for the brown and white shrimp stocks. Projections of yields at fishing levels much removed from current rates are also probably not very reliable because of the lack of actual observations at those levels. It is not likely that a recruitment overfishing problem exists for the pink shrimp stock, but environmental changes may have caused the decline in recruitment this past year.

CONCLUSIONS

Brown Shrimp

1. The increased yield experienced over the past 28 years is attributable to an increase in recruitment and not an increase in effort.
2. The increased recruitment is not attributable to an increase in parent stock, but the real cause is unknown at this time.

3. No well defined stock-recruitment relationships are apparent.
4. Stock-recruitment models suggest that full exploitation of the stock is happening at this time.
5. No real potential exists for increasing yield by simply increasing fishing effort, but the potential does exist for increasing yield by delaying the onset of fishing.

White Shrimp

1. The decrease in landings this last year is attributable to poor recruitment.
2. Long term net increase in recruitment visible over the 28 year period, with a noticeable drop this last year.
3. The decrease in recruitment this past year maybe attributable to recruitment overfishing.
4. Stock-recruitment relationships seem apparent, and other trends support the findings, even though a strong component of variation unrelated to fishing has been important in establishing the form of the relationship.
5. If stock-recruitment models are accepted, the results

indicate that the fishery has exceeded full exploitation.

6. If stock-recruitment models are accepted, then yield can be increased with the current fishing pattern by decreasing effort. Delaying fishing also has a positive effect on yield.
7. If no stock-recruitment relationship is accepted, little gain in yield can be seen by either delaying the onset of fishing or increasing effort.

Pink Shrimp

1. The fishery has been very stable over most of the historical period.
2. A problem with recruitment this last season is a concern, even though parent stock levels are still quite normal.
3. There exists some potential to increase yield by either increasing effort and/or reducing fishing on newly recruited shrimp.

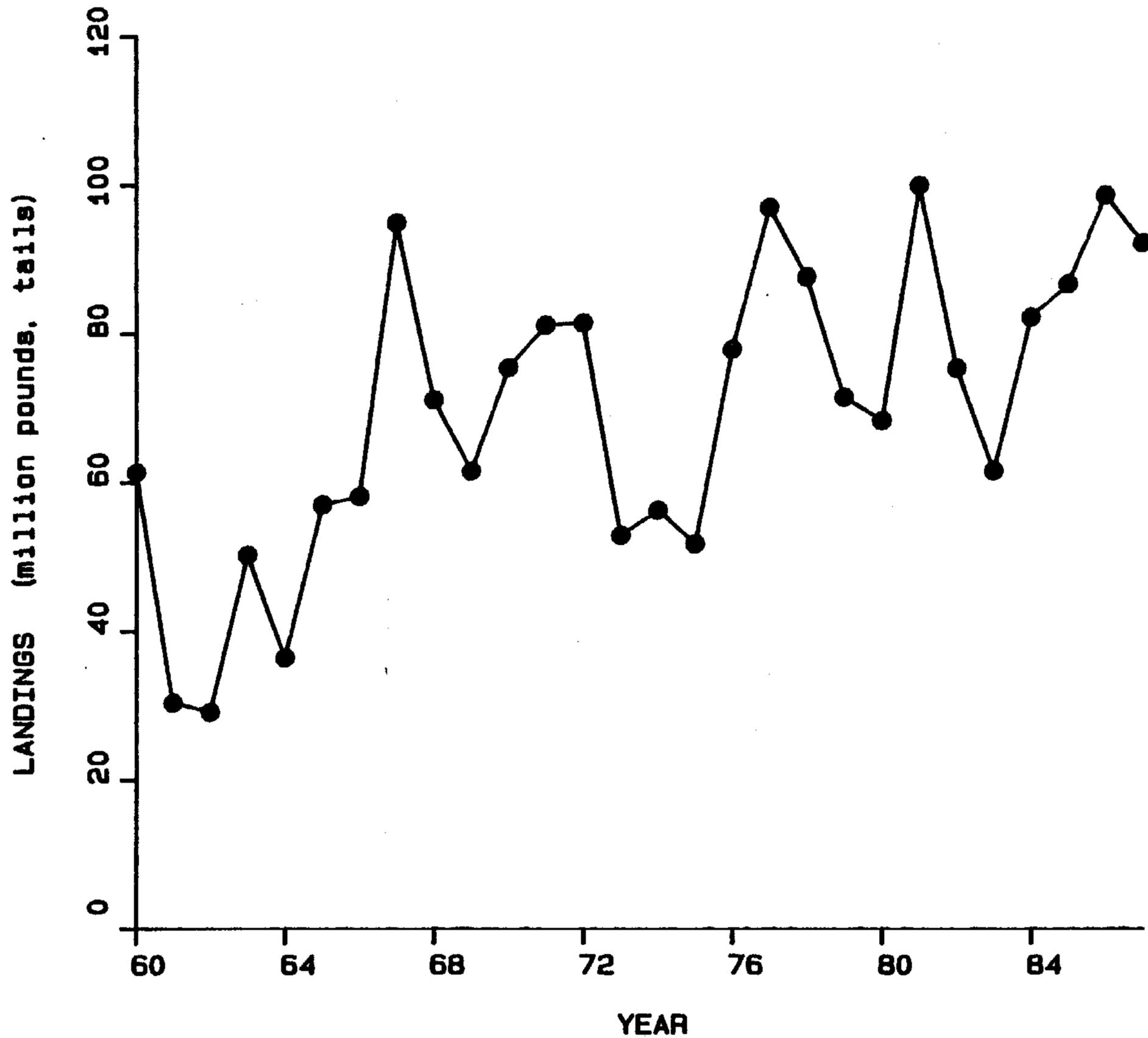
LITERATURE CITED

- Brunenmeister, S. L. 1980. Commercial brown, white and pink shrimp tail size: total size conversions. NOAA Tech. Memo. NMFS-SEFC-20.
- Nichols, S. 1981. Growth rates of white shrimp as functions of shrimp size and water temperature. Paper presented at the Workshop on the Scientific Basis for the Management of Penaeid Shrimp, Key West, Florida, November 1981.
- Nichols, S. 1984. Updated assessments of brown, white and pink shrimp in the U.S. Gulf of Mexico. Paper presented at the Workshop on Stock Assessment. Miami, Florida, May 1984.
- Nichols, S. 1986. Stock assessment of brown, white and pink shrimp in the U.S. Gulf of Mexico, 1960-1985. NOAA Tech. Memo. NMFS-SEFC-179.
- Nichols, S. and N. J. Cummings. 1984. Investigations of commercial catch per effort data for indexing brown shrimp recruitment. Paper presented at the Workshop on Stock Assessment. Miami, Florida, May 1984.
- Parrack, M. L. 1981. Some aspects of brown shrimp exploitation in the northern Gulf of Mexico. Paper presented at the

Workshop on the Scientific Basis for the Management of
Penaeid Shrimp. Key West, Florida, November 1981.

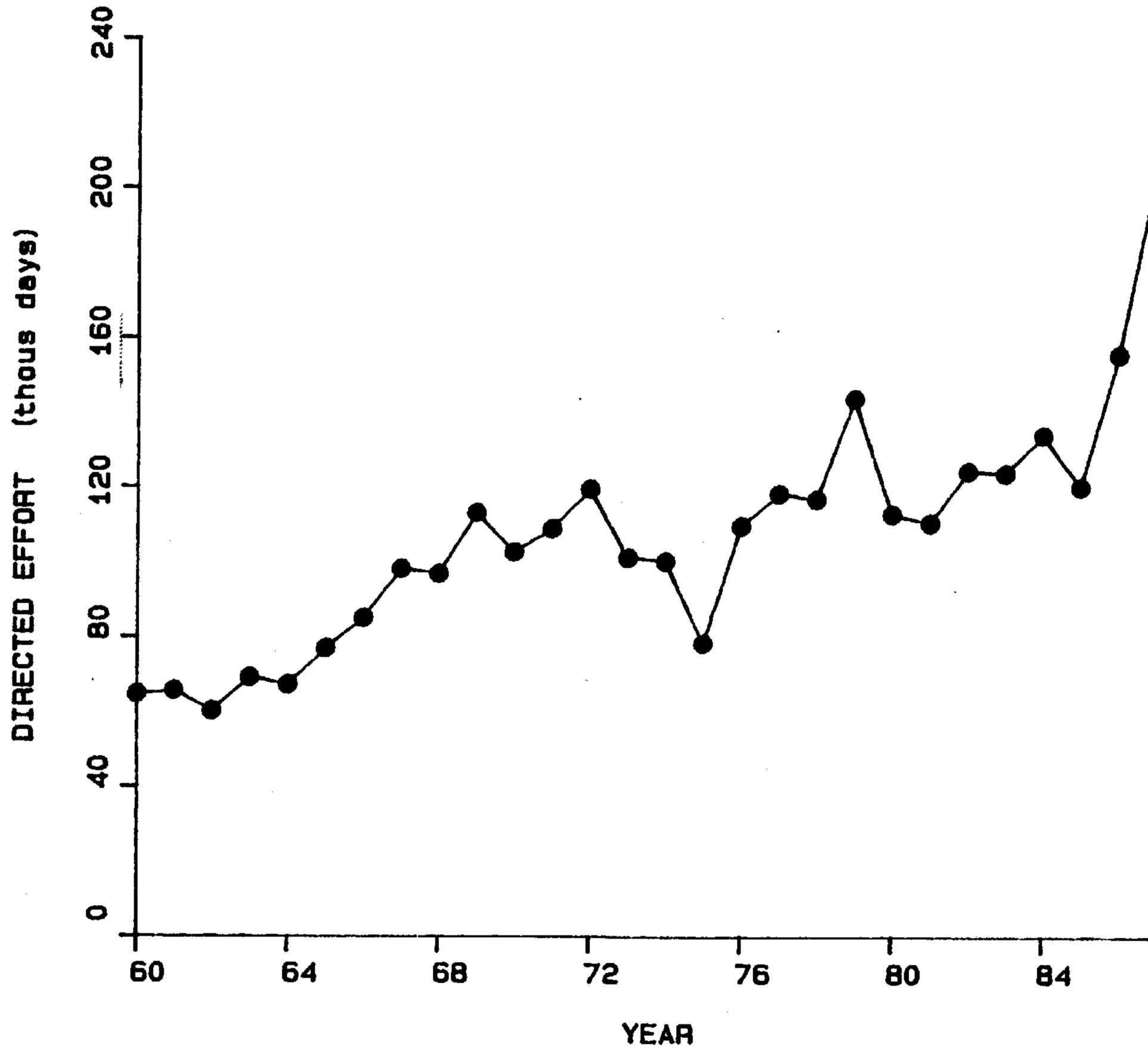
Phares, P. L. 1980. Tail length to tail weight relationships
for Louisiana white shrimp in 1977. NOAA Tech. Memo. NMFS-
SEFC-57.

BROWN SHRIMP



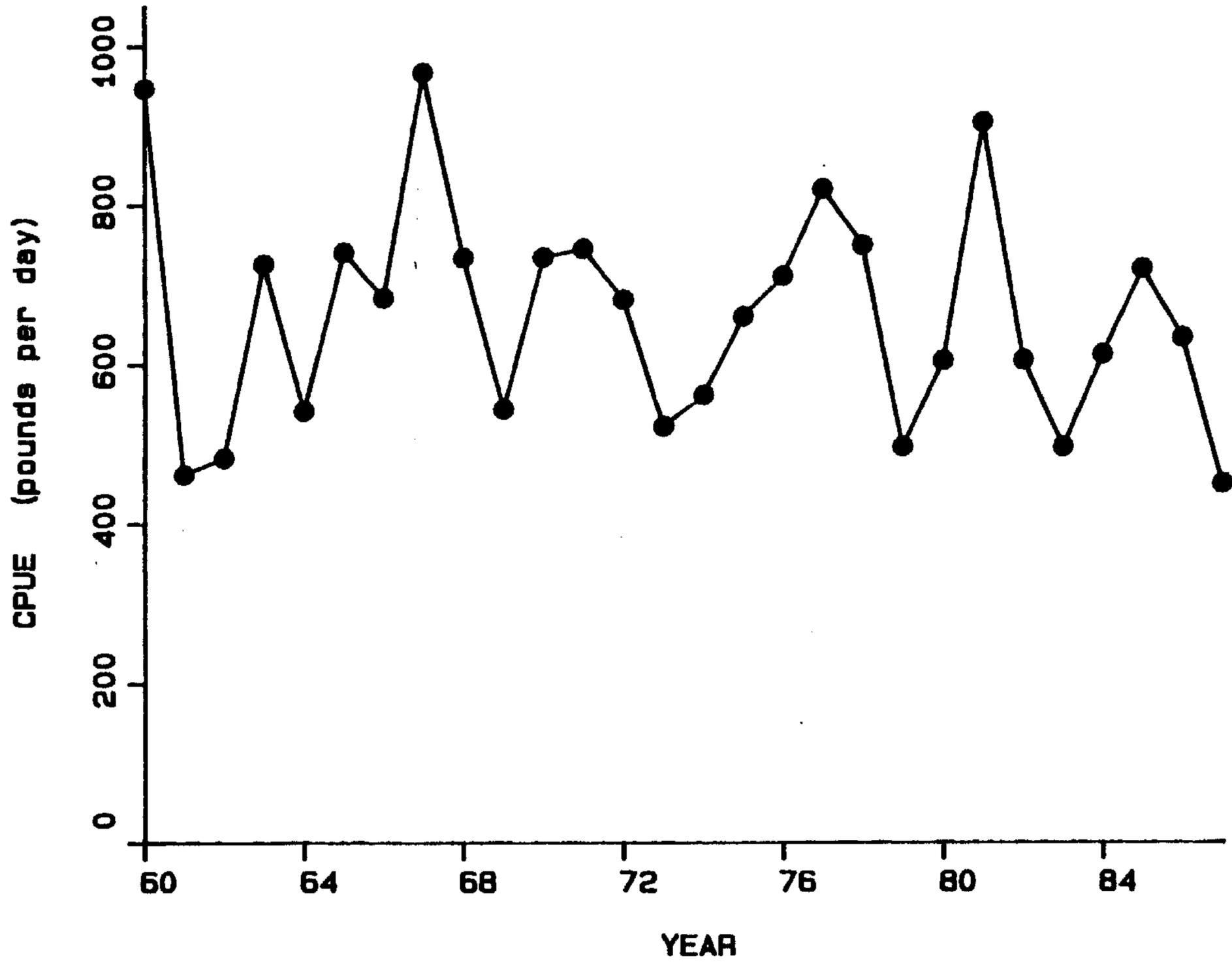
1. Reported annual landings for brown shrimp.

BROWN SHRIMP



2. Estimated annual directed effort for brown shrimp.

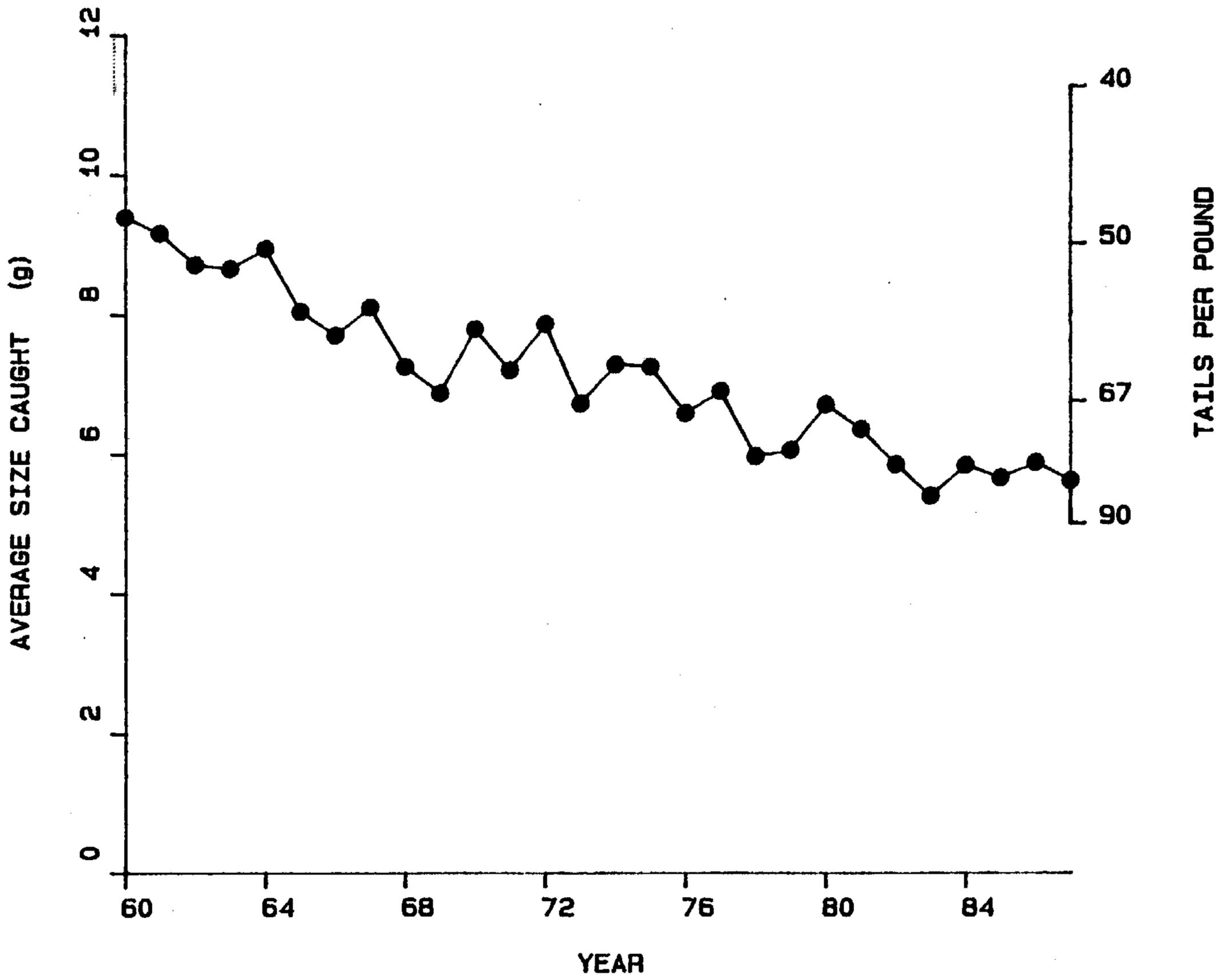
BROWN SHRIMP



3. Estimated annual average catch per unit effort for brown shrimp.

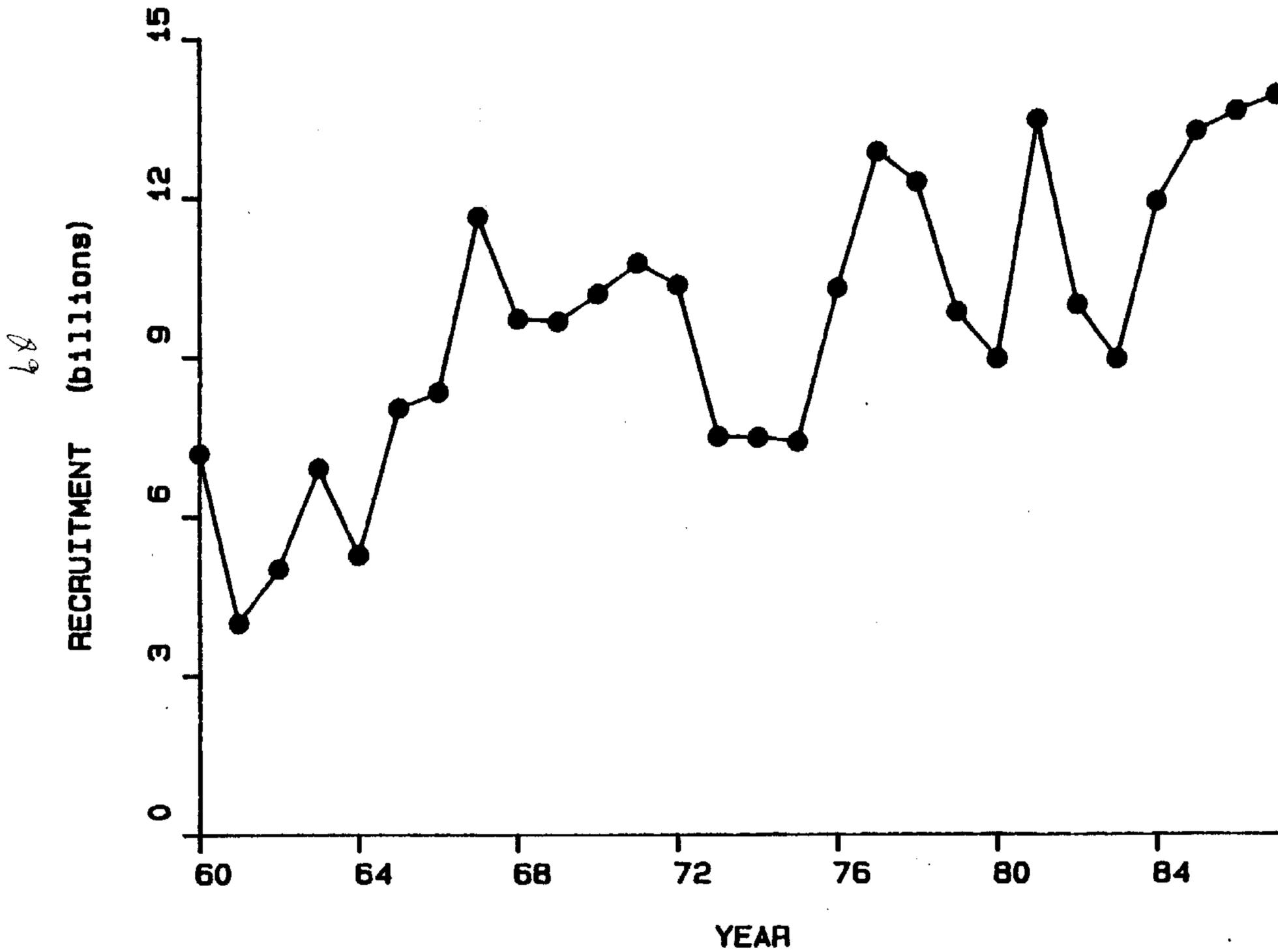
BROWN SHRIMP

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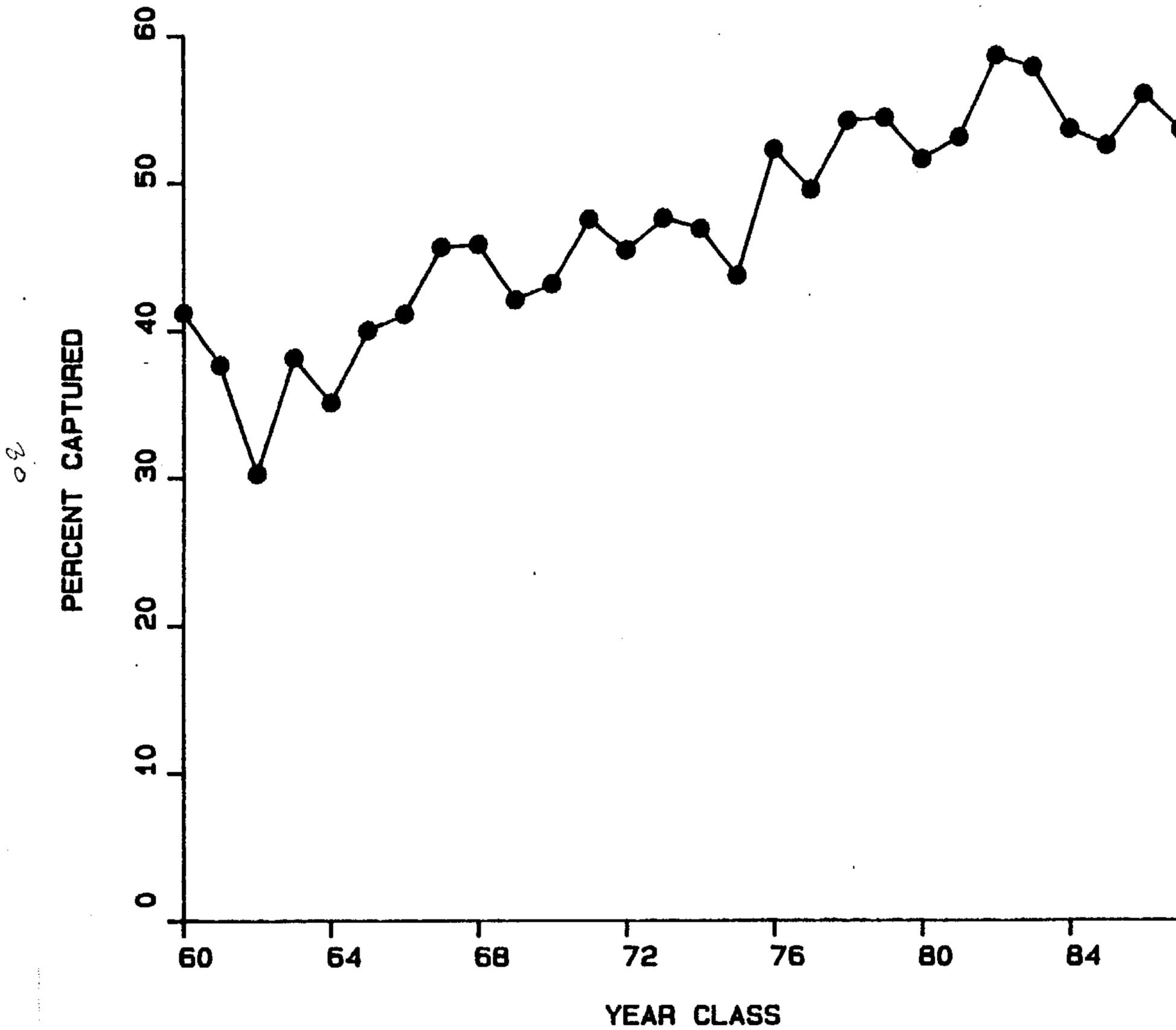
4. Annual average size of brown shrimp landed.

BROWN SHRIMP



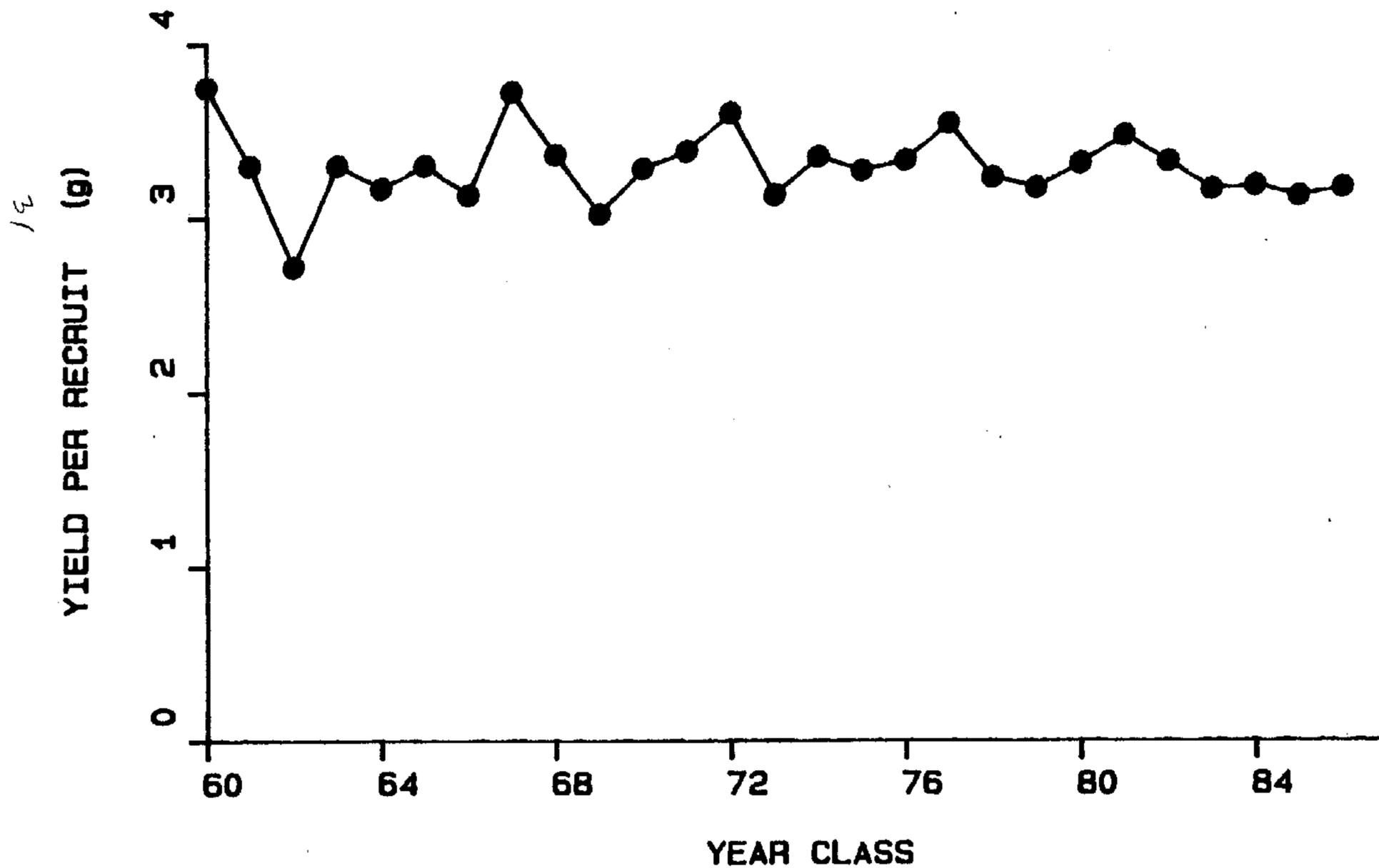
5. Estimated annual recruitment for brown shrimp.

BROWN SHRIMP



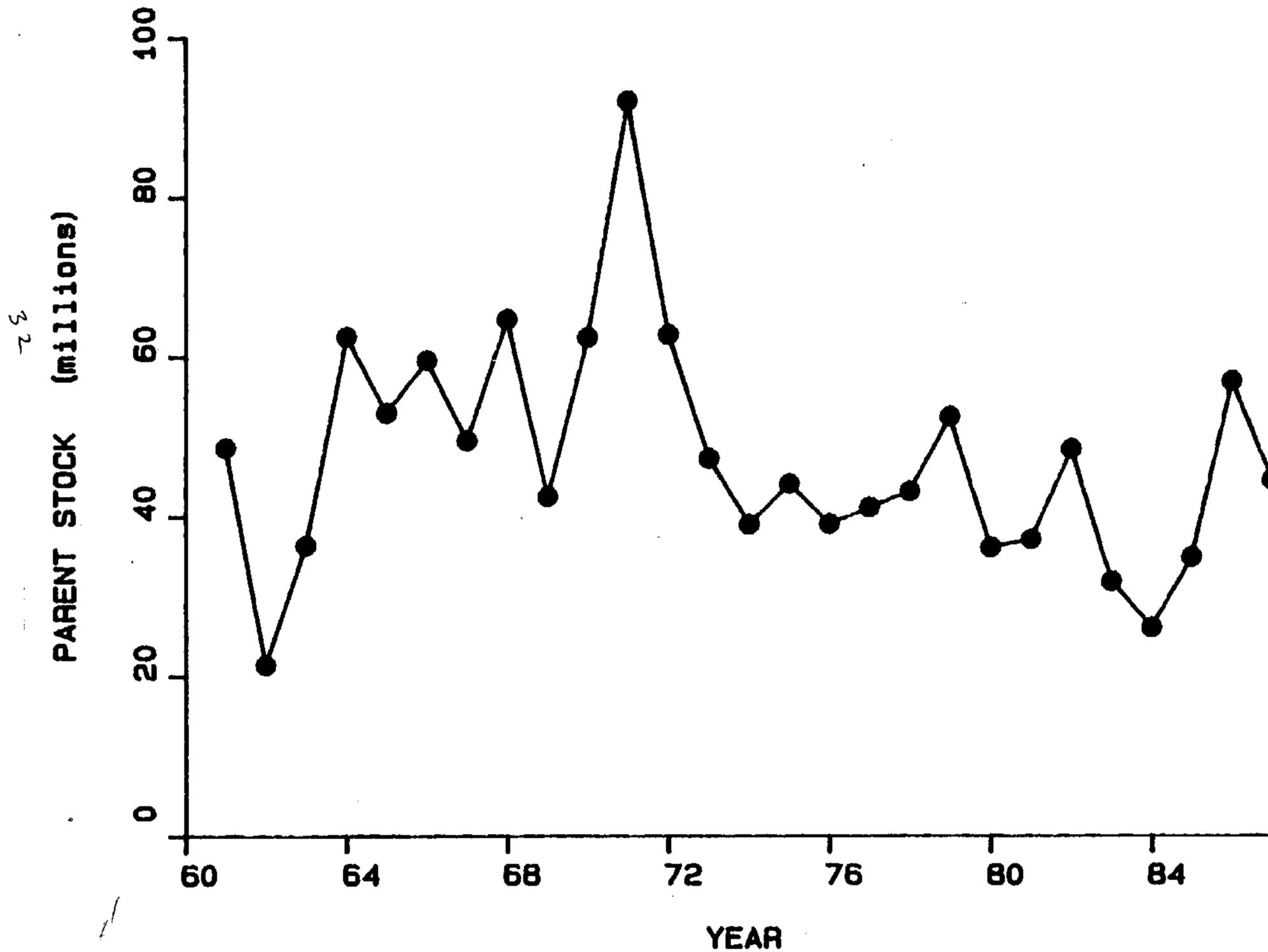
6. Percentage of brown shrimp recruits captured by the fishery from each year-class.

BROWN SHRIMP



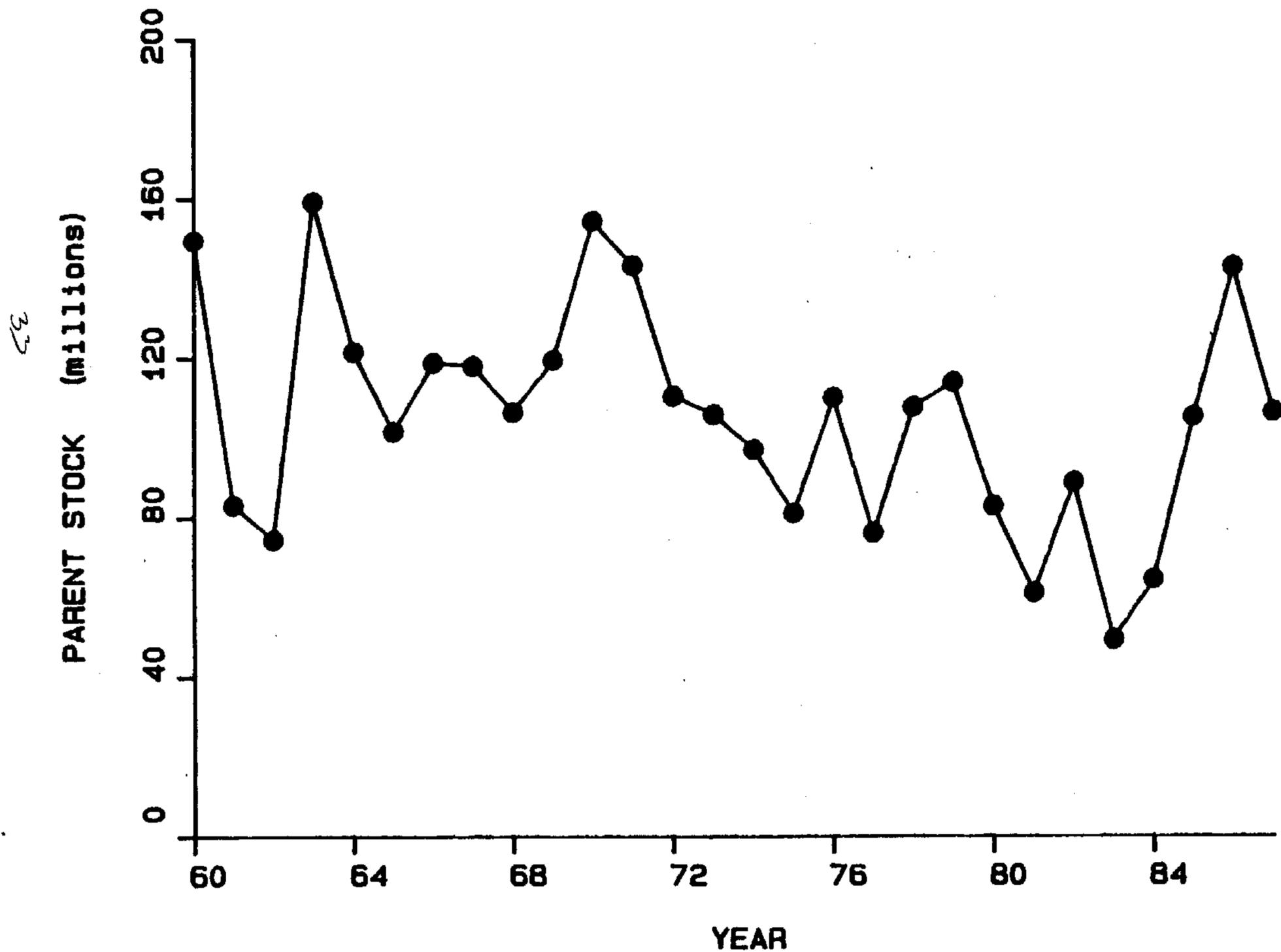
7. Estimated realized yield per recruit for each brown shrimp year-class.

BROWN SHRIMP



8. Estimated parent stock size (age 7+) for brown shrimp during November.

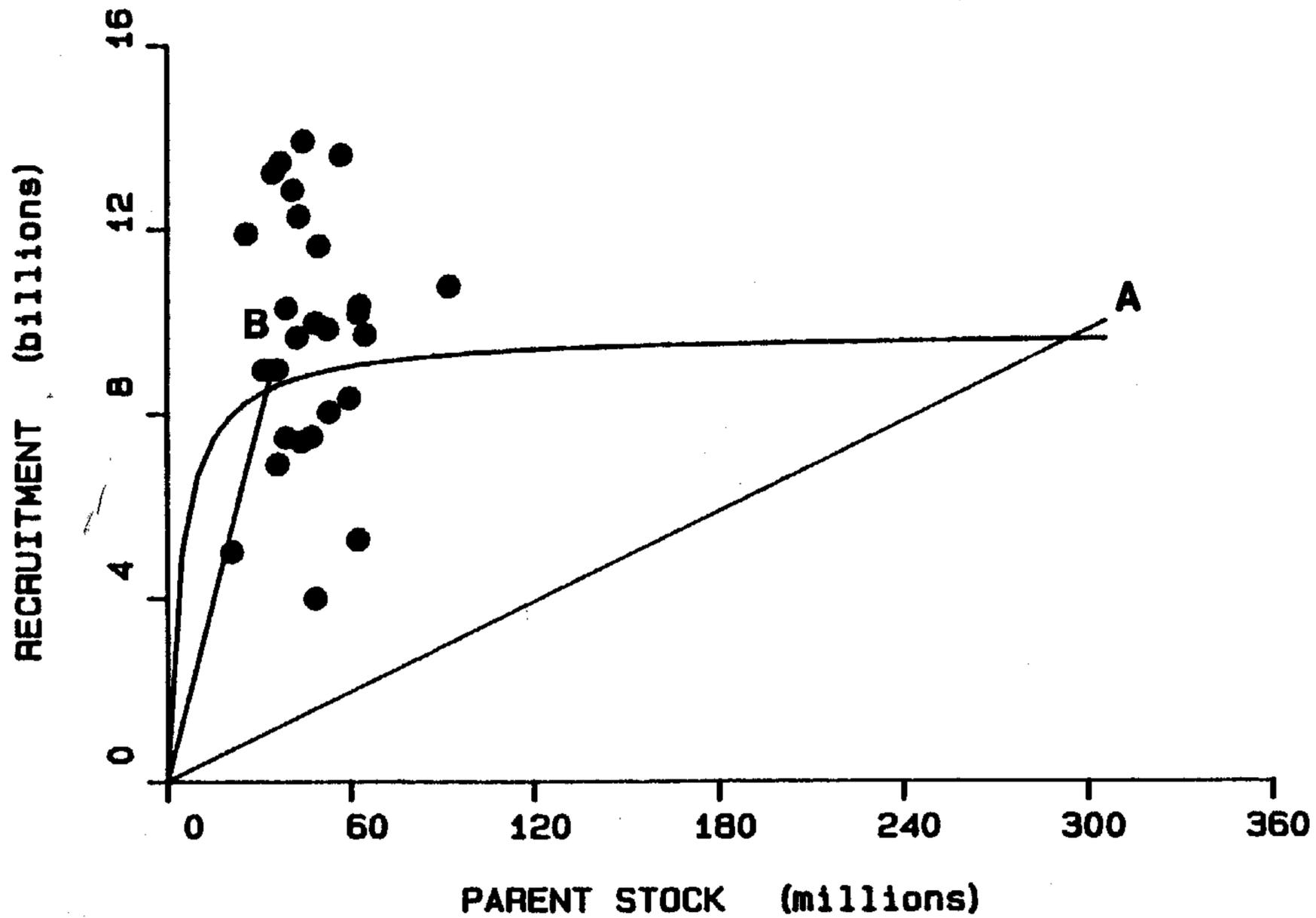
BROWN SHRIMP



9. Estimated parent stock size (age 6+) for brown shrimp during February.

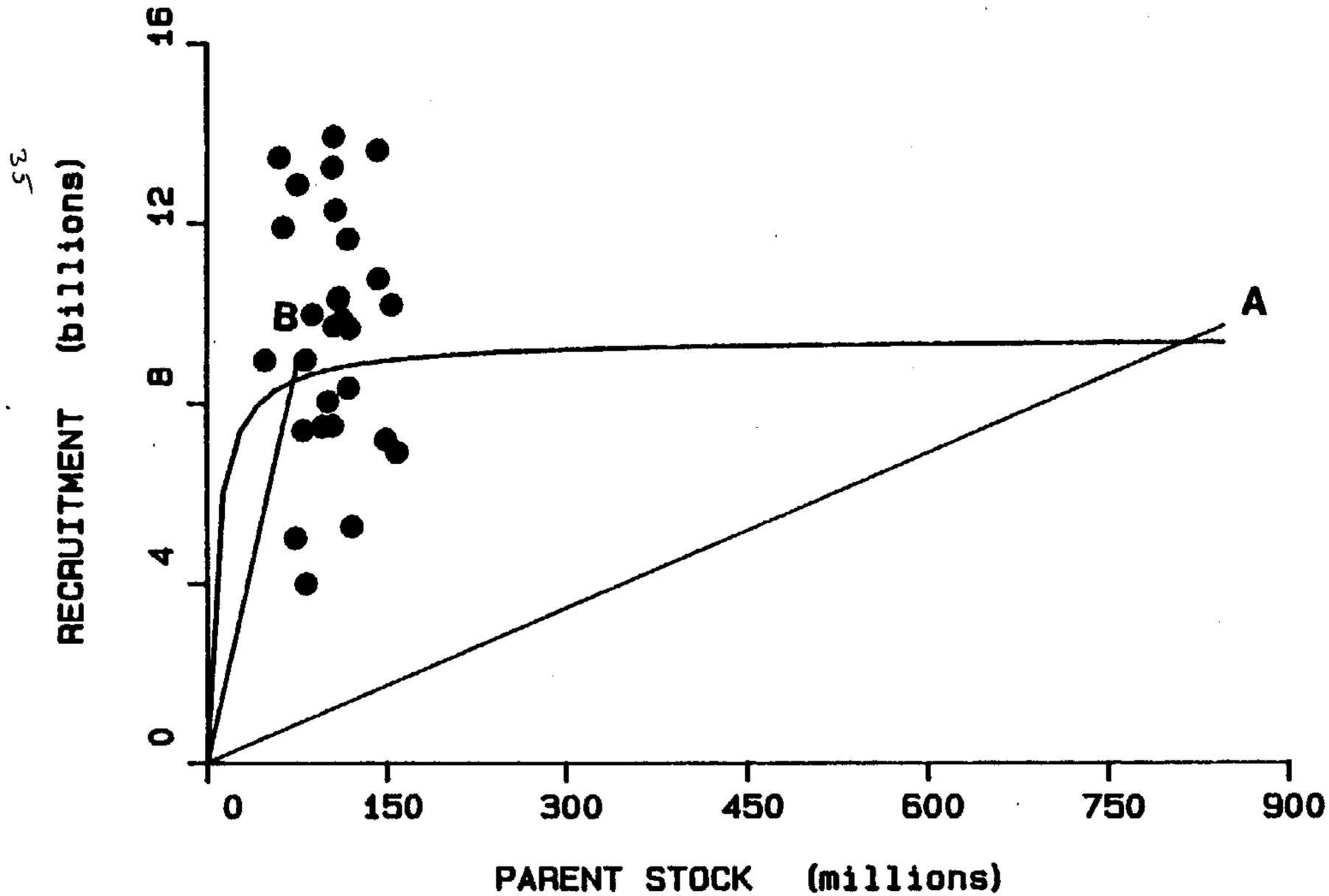
BROWN SHRIMP

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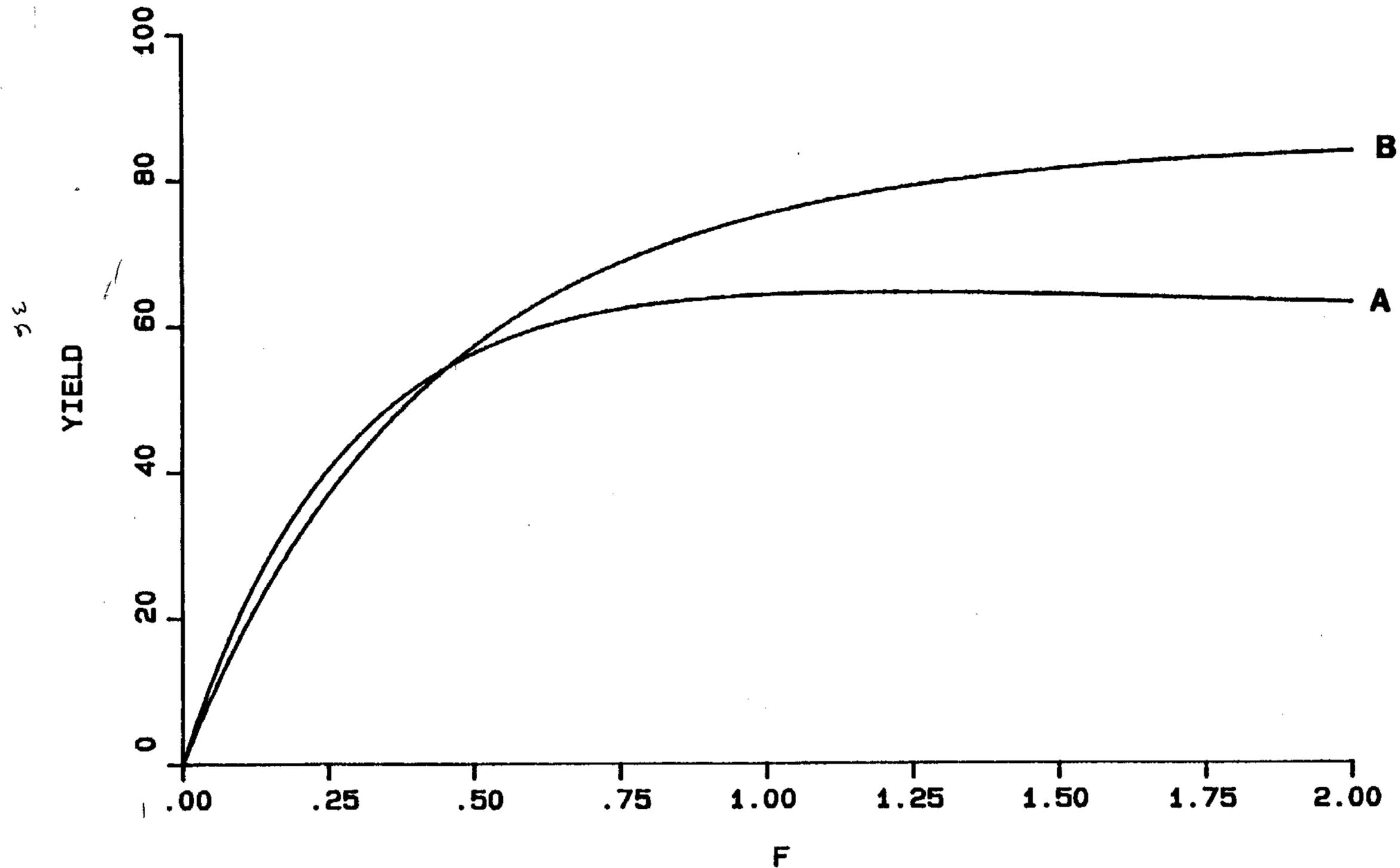
10. Brown shrimp stock-recruitment relationship between annual recruitment and November parent stock. A: replacement line with no fishing; B: replacement line at maximum sustainable

BROWN SHRIMP



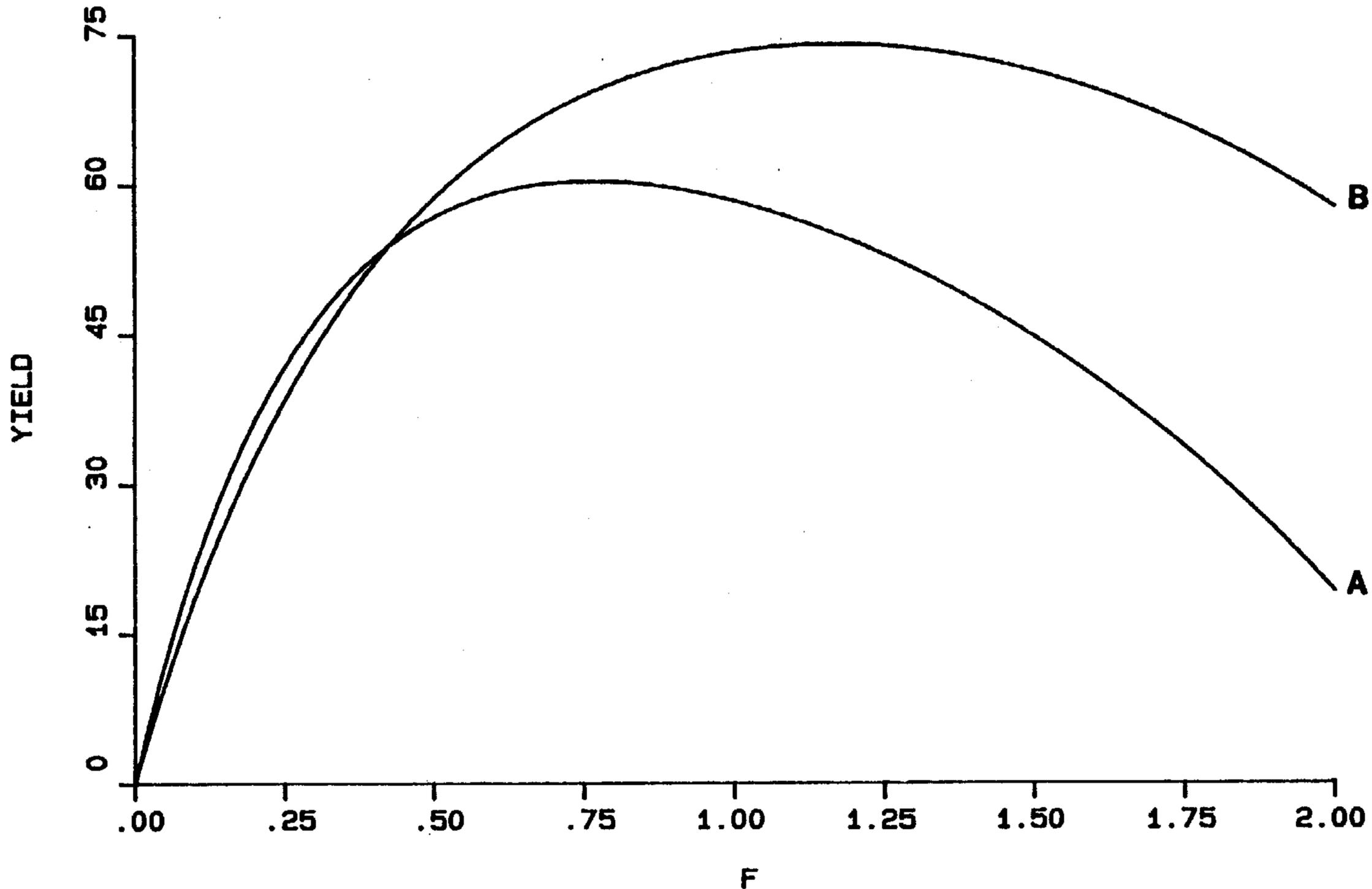
11. Brown shrimp stock-recruitment relationship between annual recruitment and February parent stock. A: replacement line with no fishing; B: replacement line at maximum sustainable recruitment

BROWN SHRIMP



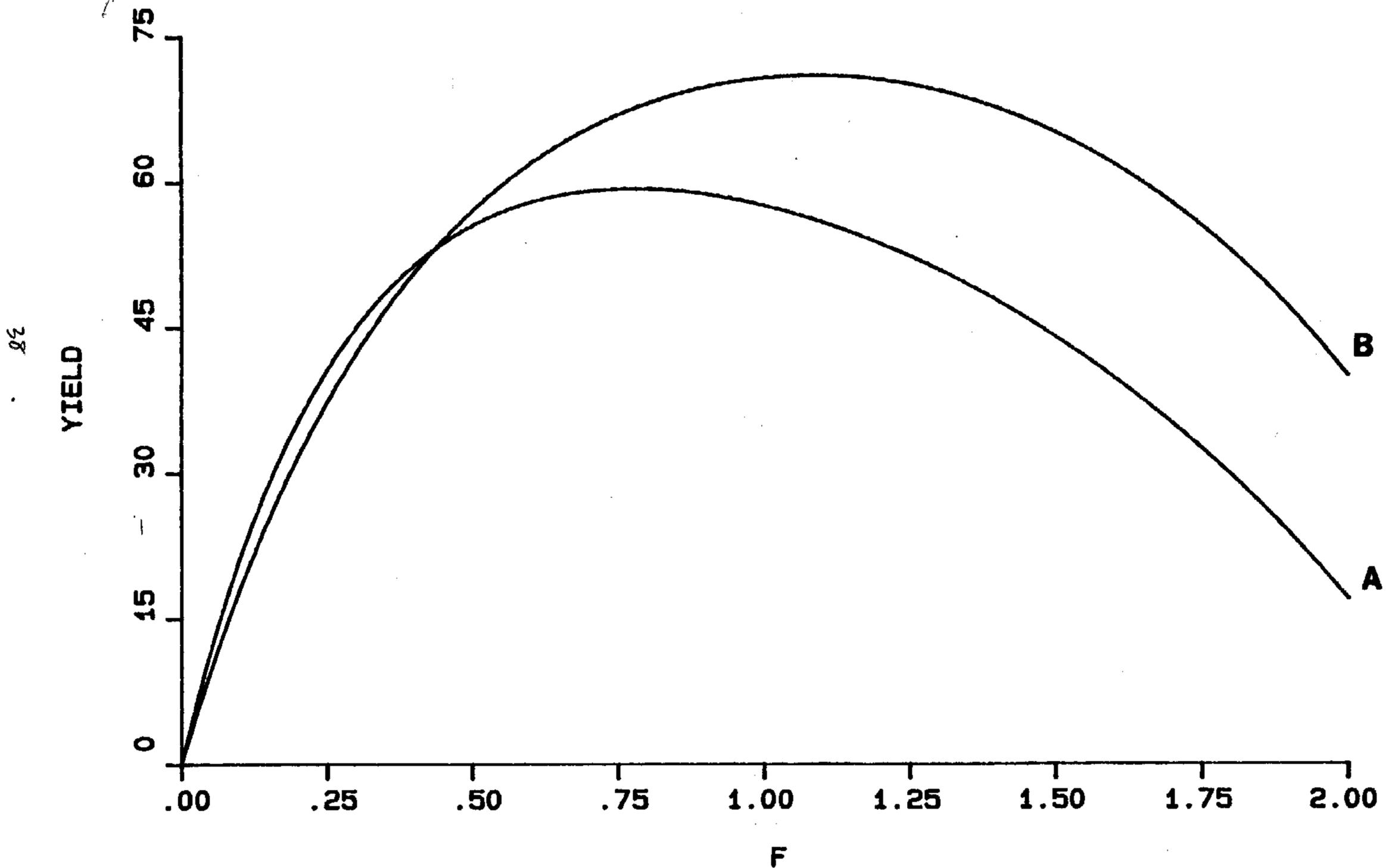
12. Projected yields for brown shrimp assuming no stock recruitment relationship exists. Baseline fishing intensity = 1.0. A: yield curve for the present fishing pattern; B: yield curve with fishing on new recruits delayed until July

BROWN SHRIMP



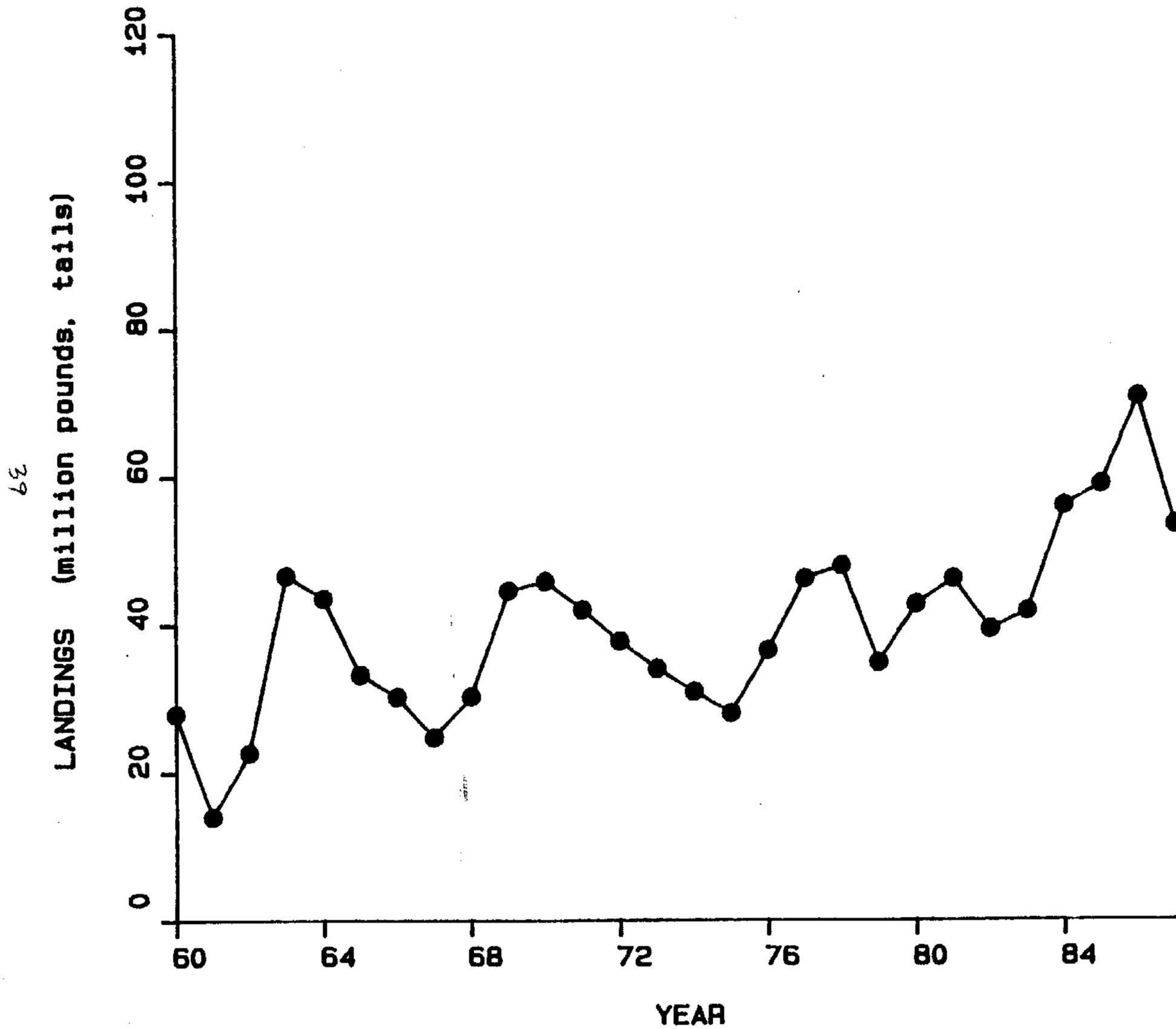
13. Projected yields for brown shrimp assuming the November stock recruitment relationship holds. A: yield curve for the present fishing pattern; B: yield curve with fishing on new recruits delayed until July.

BROWN SHRIMP



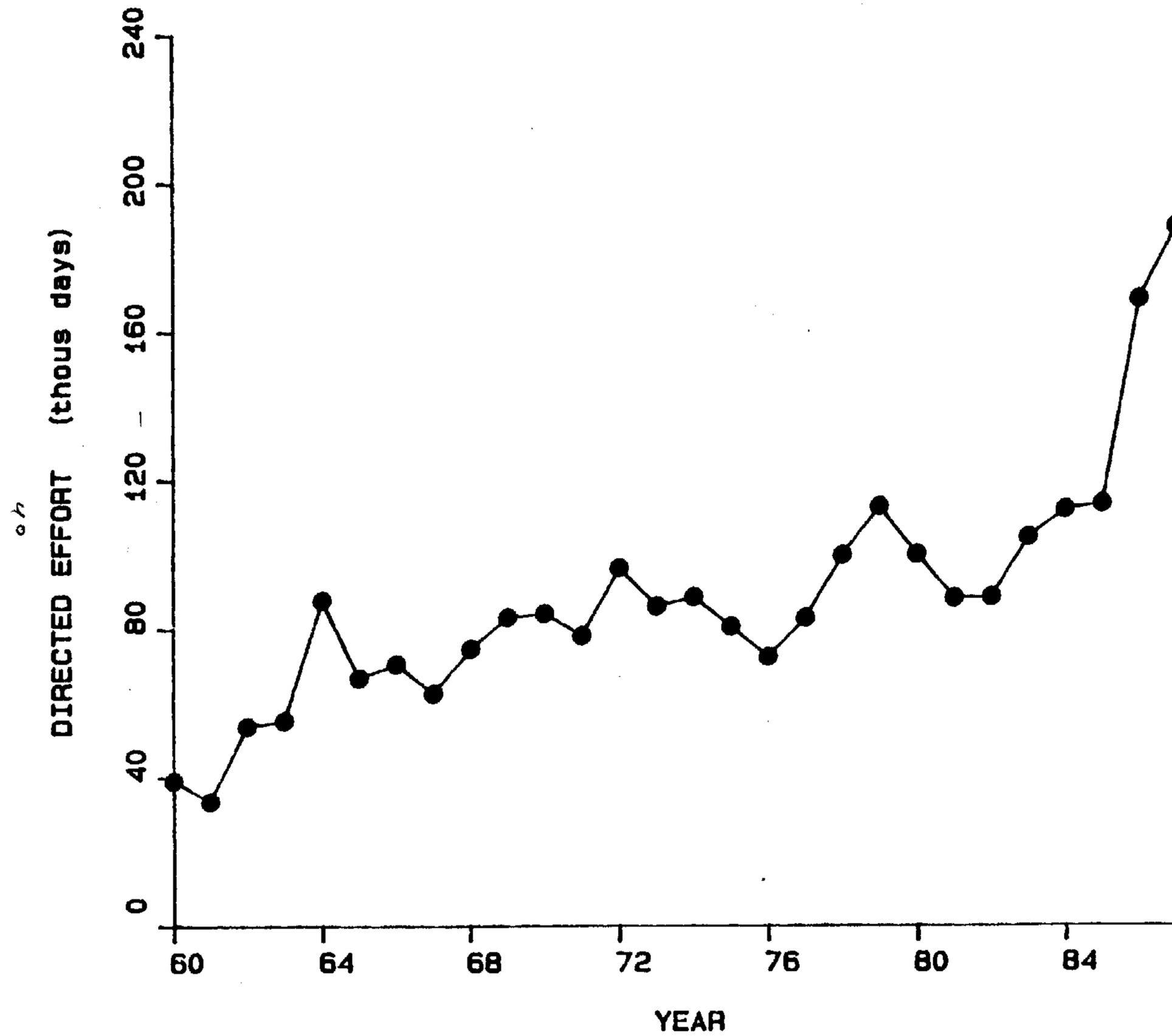
14. Projected yields for brown shrimp assuming the February stock recruitment relationship holds. A: yield curve for the present fishing pattern; B: yield curve with fishing on new recruits delayed until July.

WHITE SHRIMP



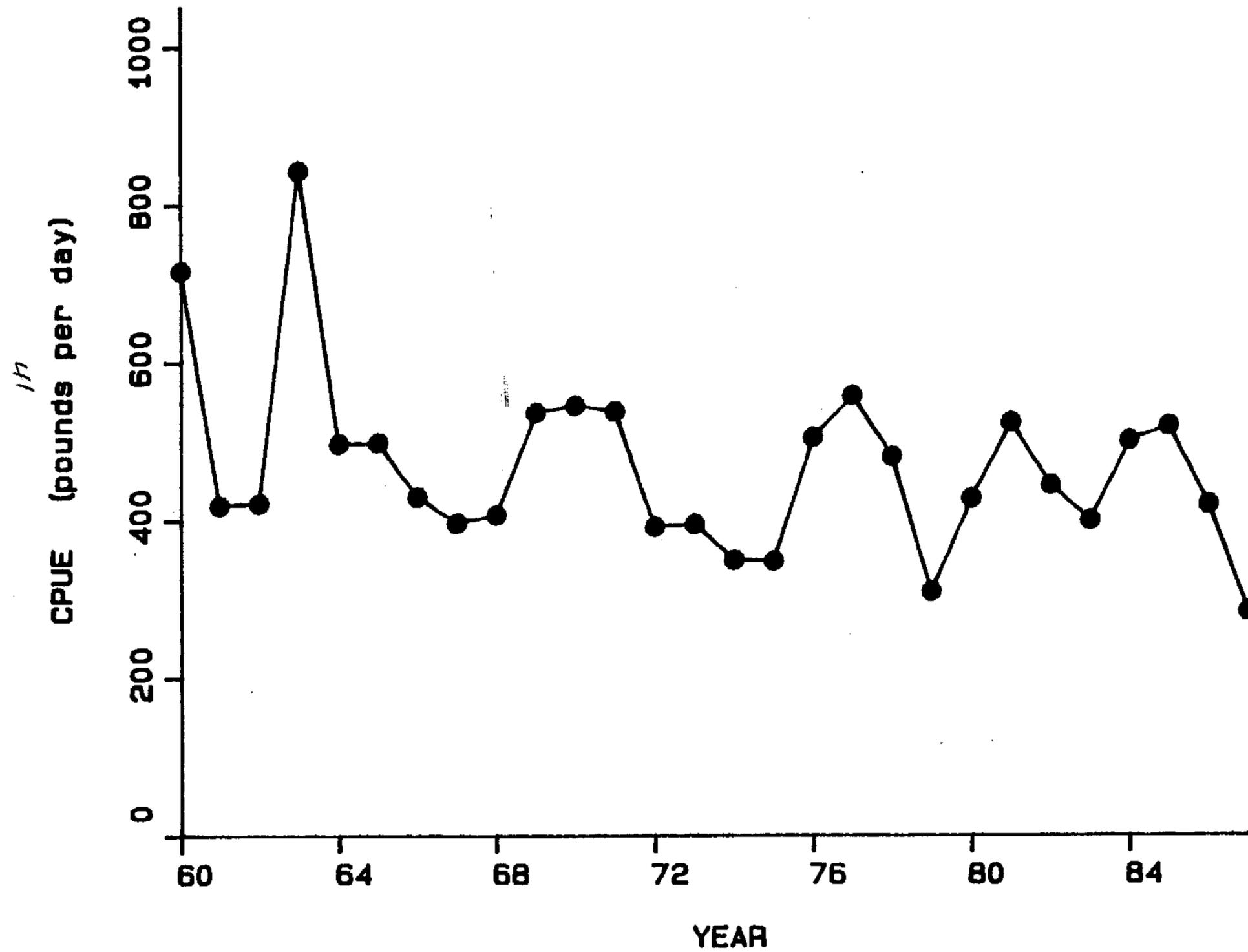
15. Reported annual landings for white shrimp.

WHITE SHRIMP



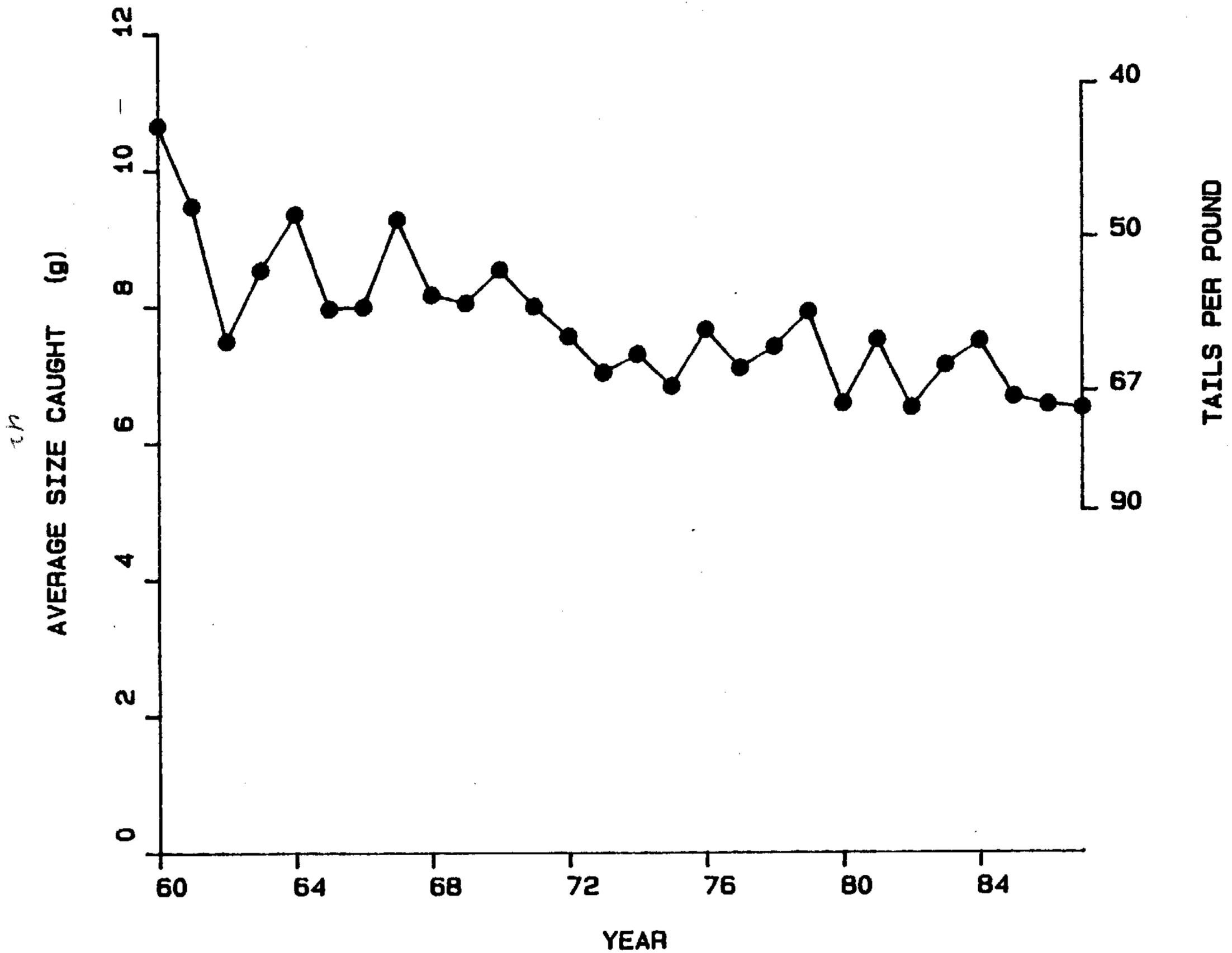
16. Estimated annual directed effort for white shrimp.

WHITE SHRIMP



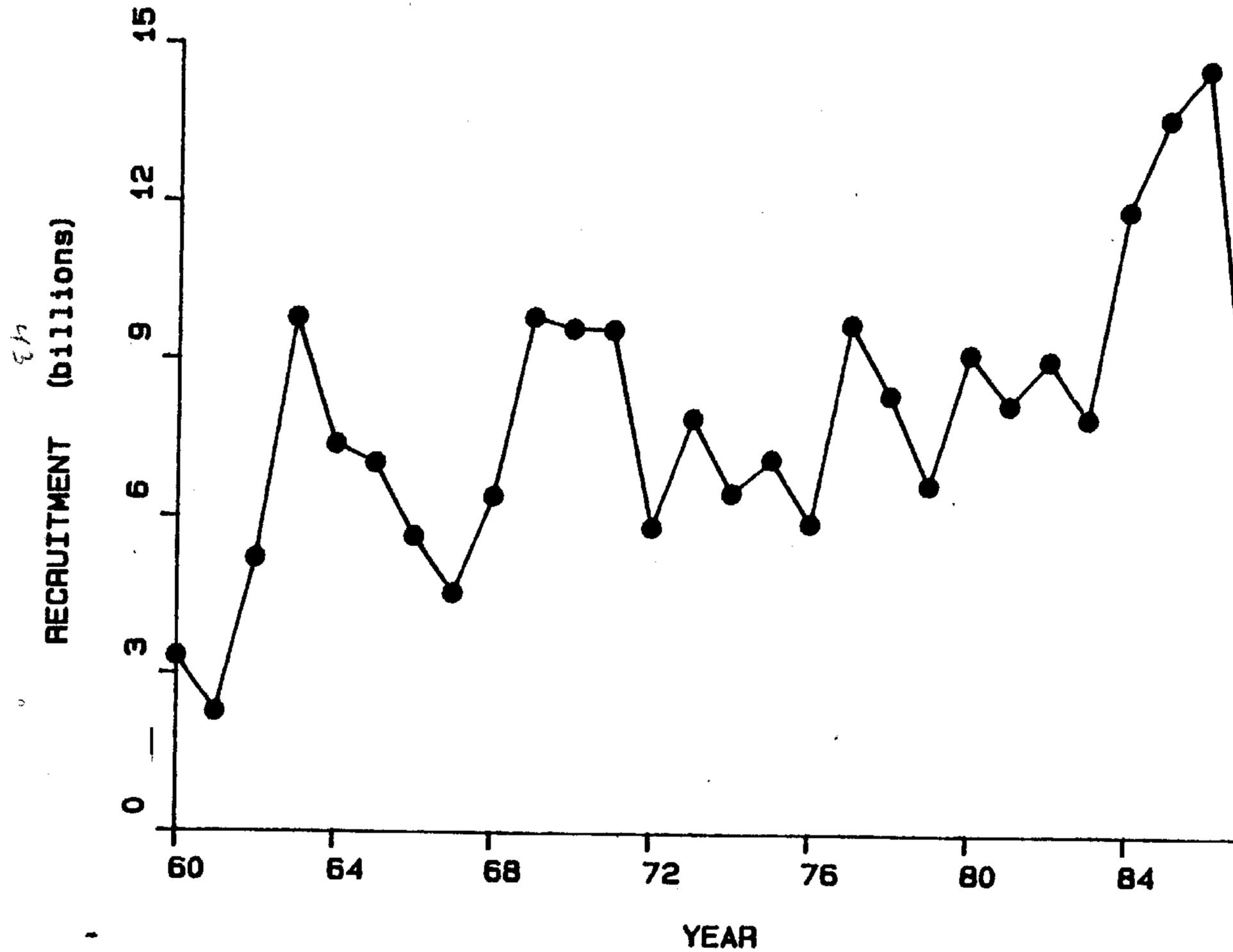
17. Estimated annual average catch per unit effort for white shrimp.

WHITE SHRIMP



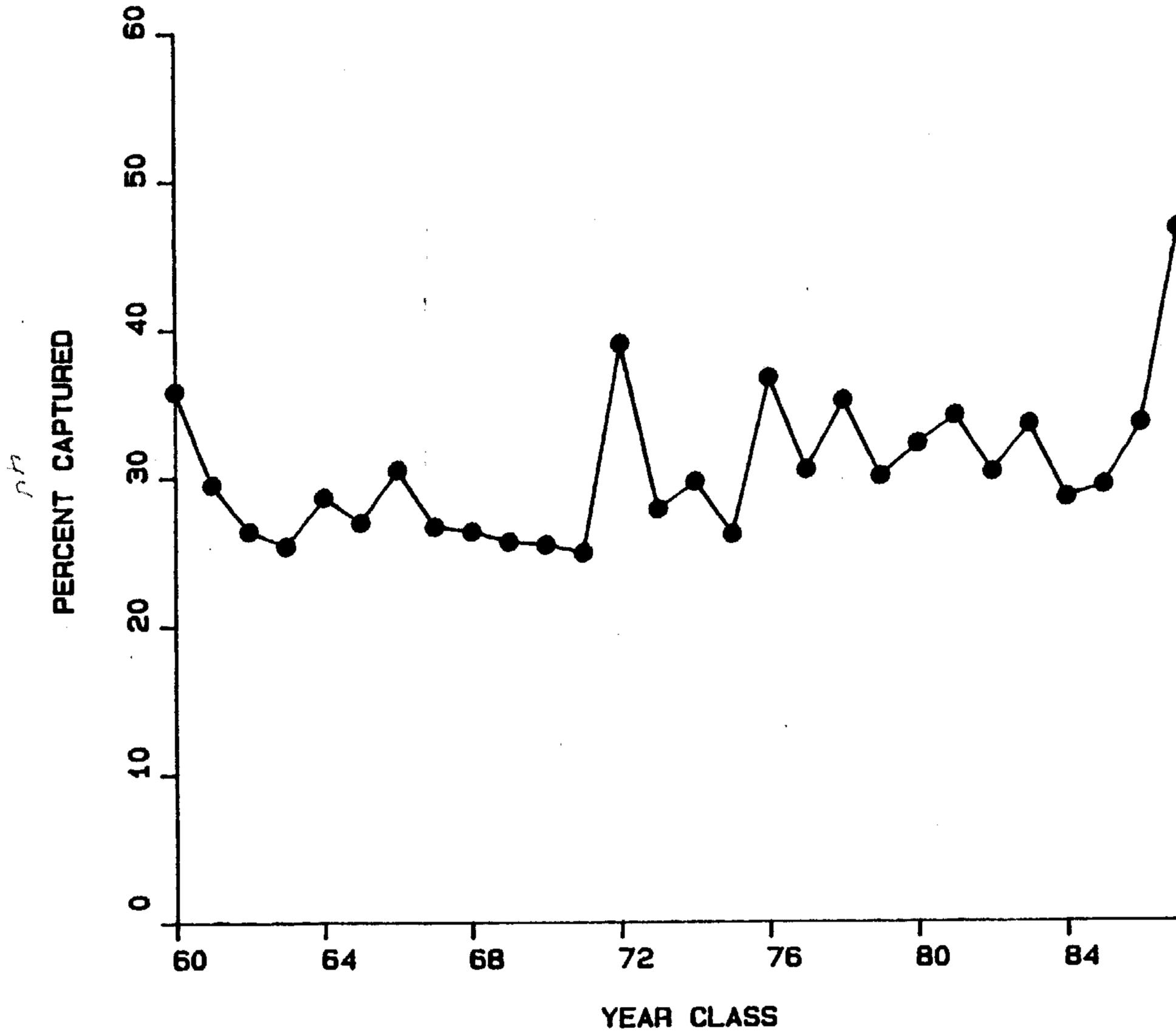
18. Annual average size of white shrimp landed.

WHITE SHRIMP



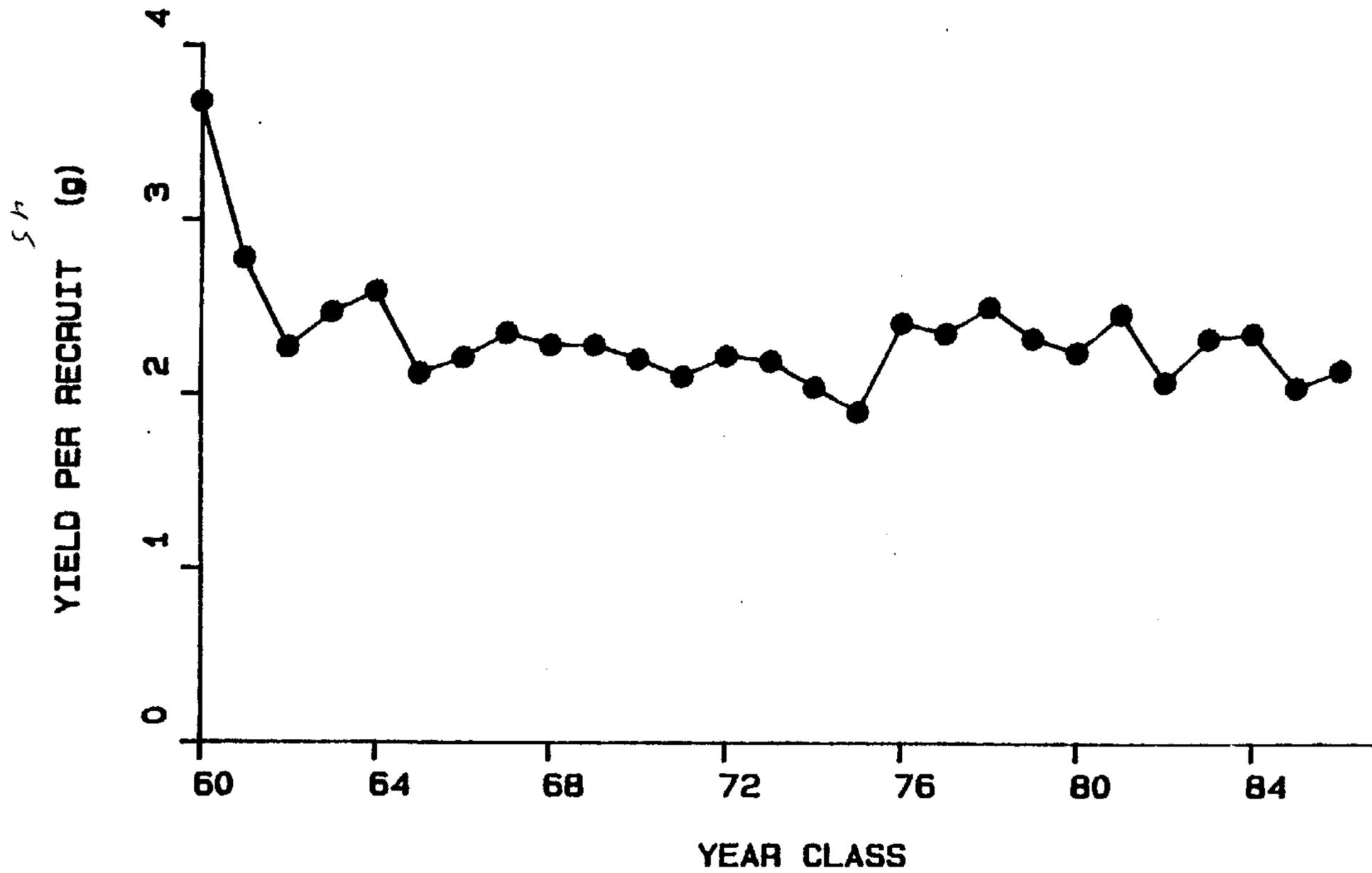
19. Estimated annual recruitment for white shrimp.

WHITE SHRIMP



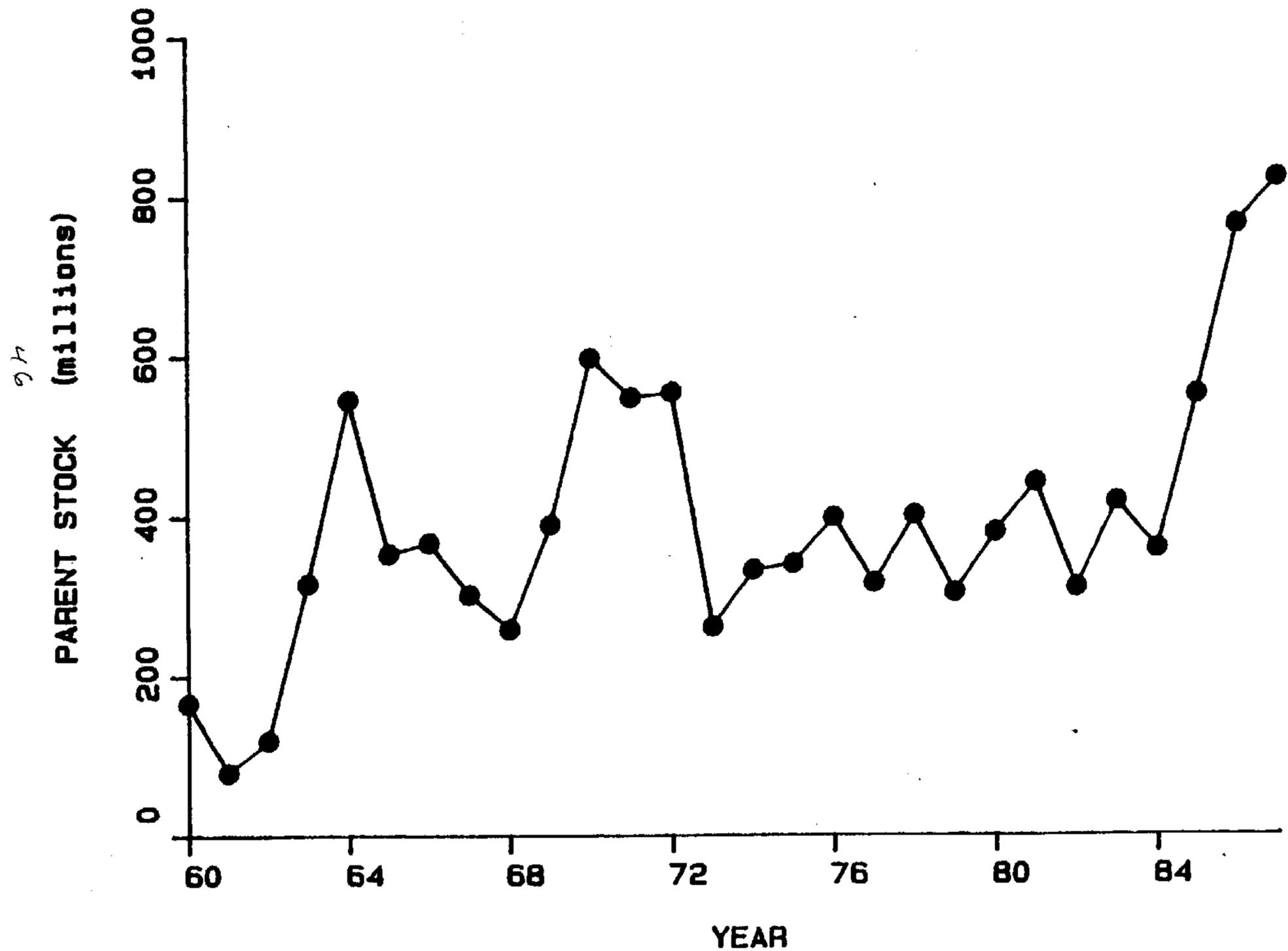
20. Percentage of white shrimp recruits captured by the fishery from each year-class.

WHITE SHRIMP



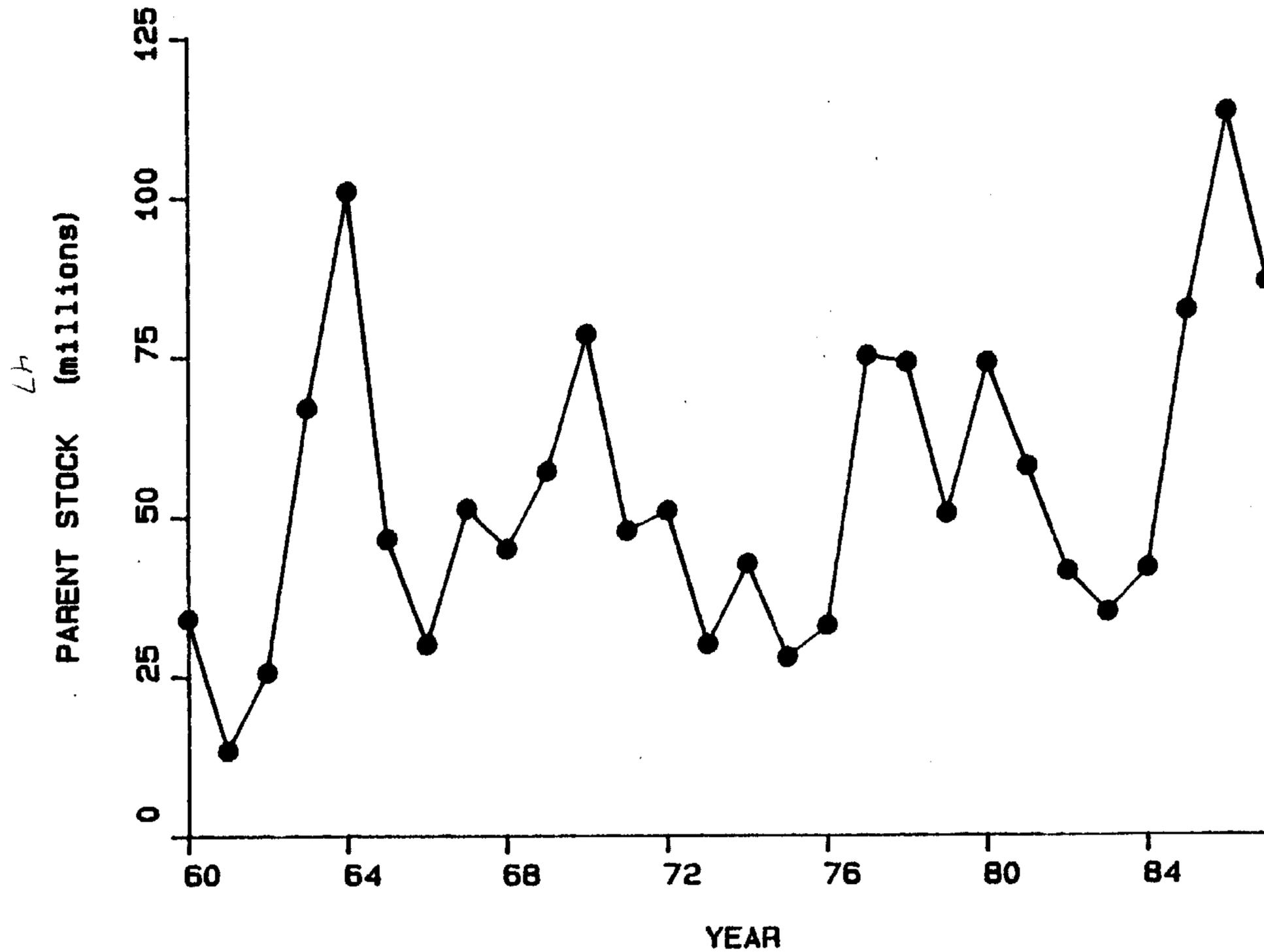
21. Estimated realized yield per recruit for each white shrimp year-class.

WHITE SHRIMP



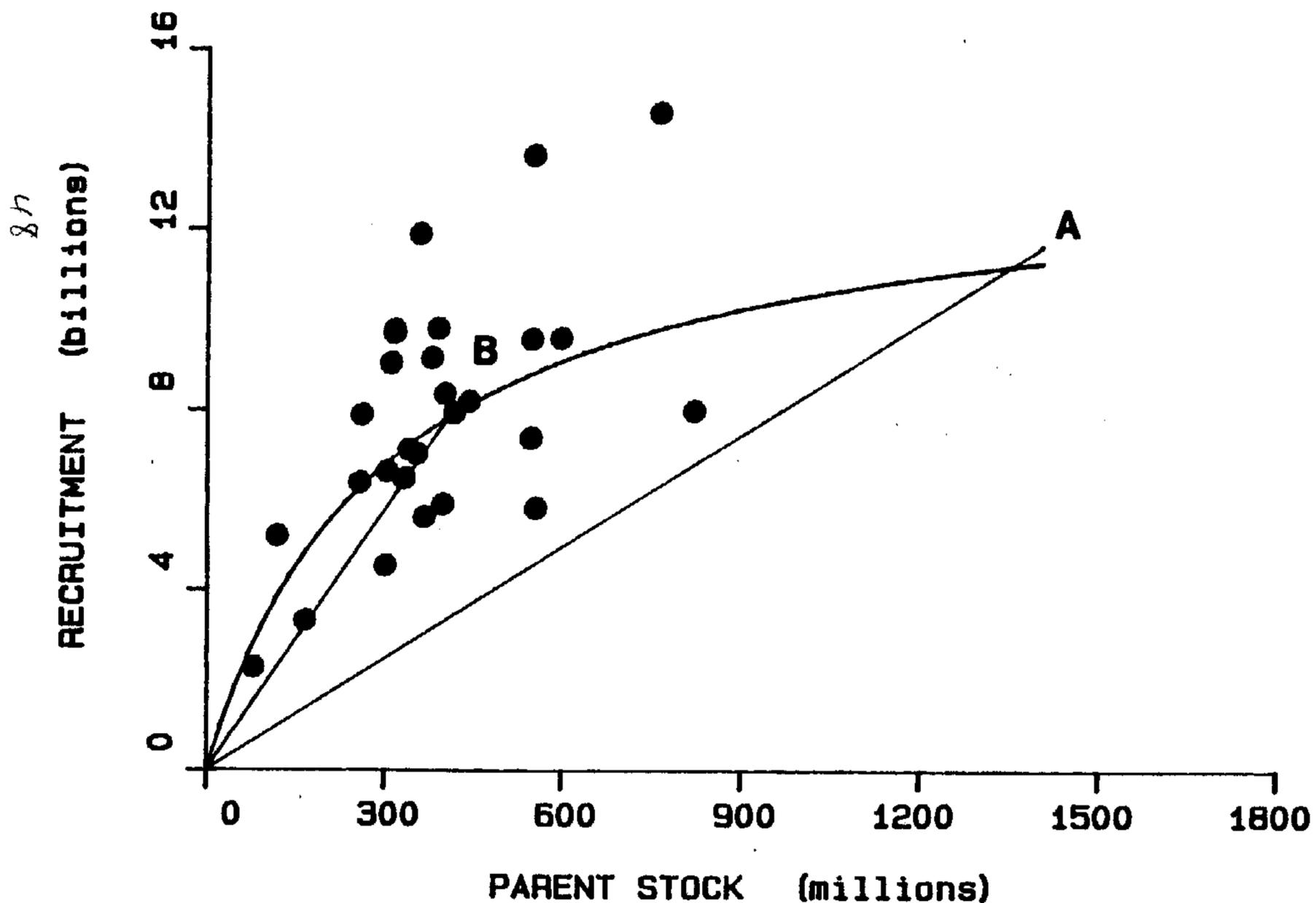
22. Estimated parent stock size (age 5+) for white shrimp during April.

WHITE SHRIMP



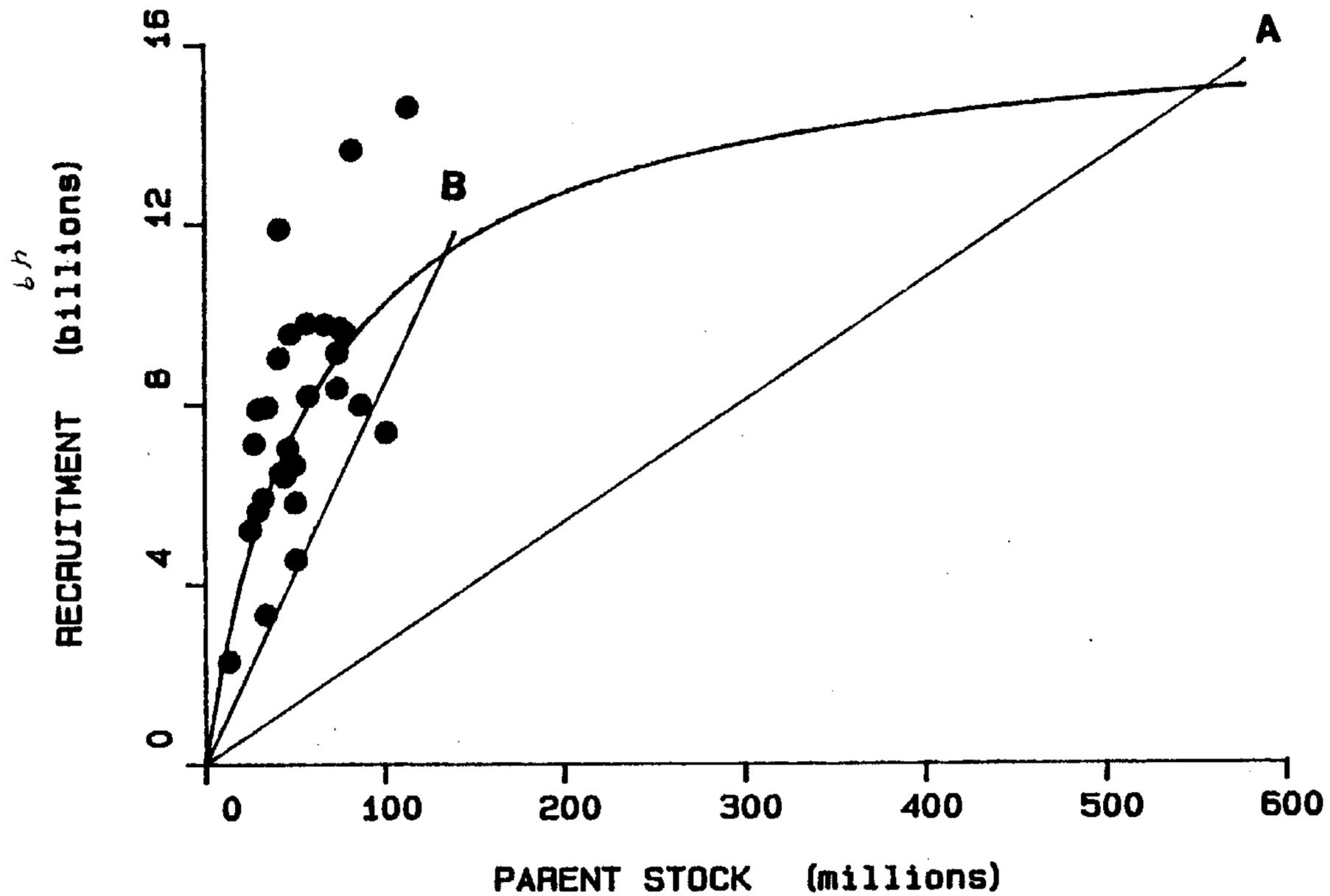
23. Estimated parent stock size (age 5+) for white shrimp during August.

WHITE SHRIMP



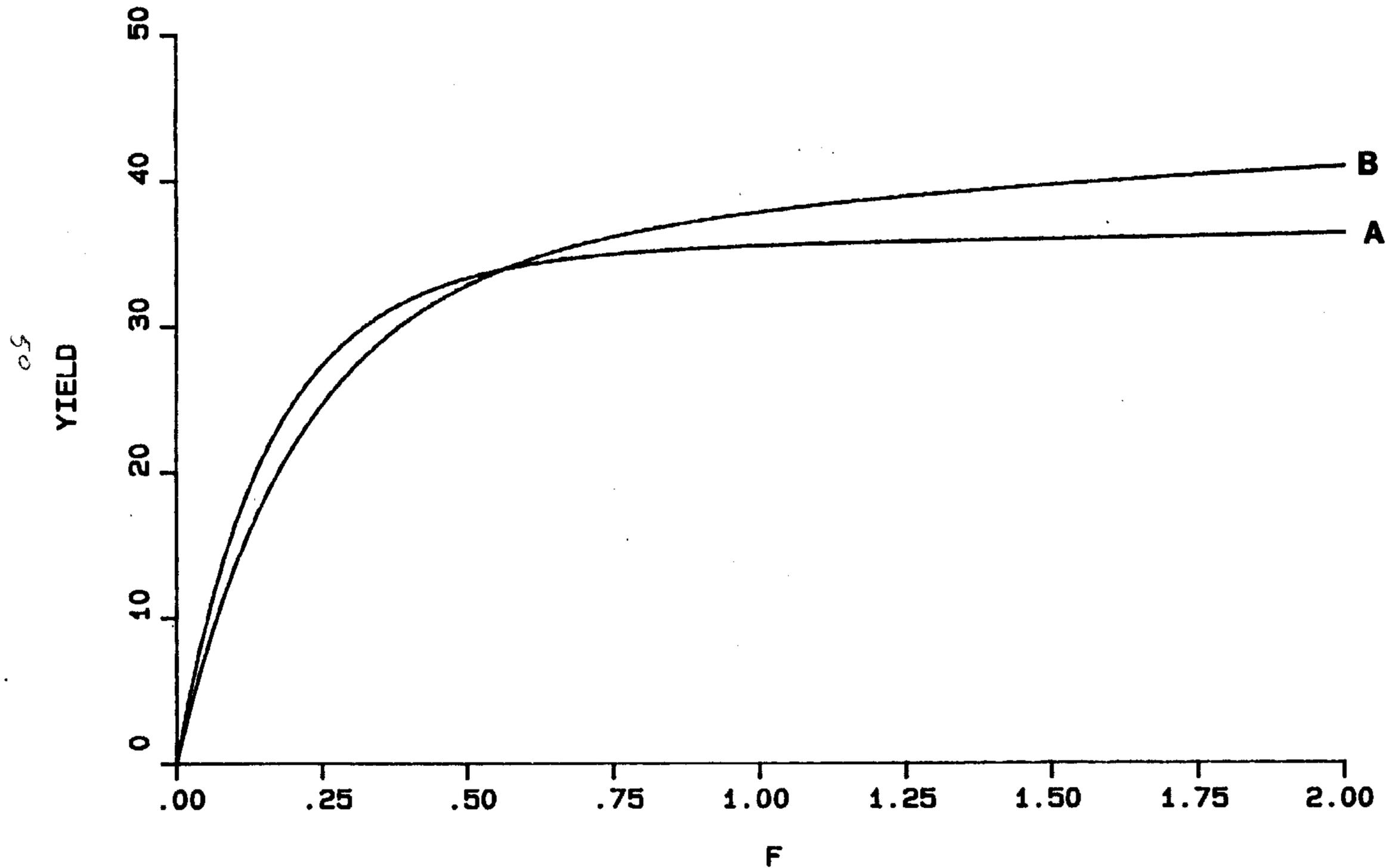
24. White shrimp stock-recruitment relationship between annual recruitment and April parent stock. A: replacement line with no fishing; B: replacement line at maximum sustainable recruitment.

WHITE SHRIMP



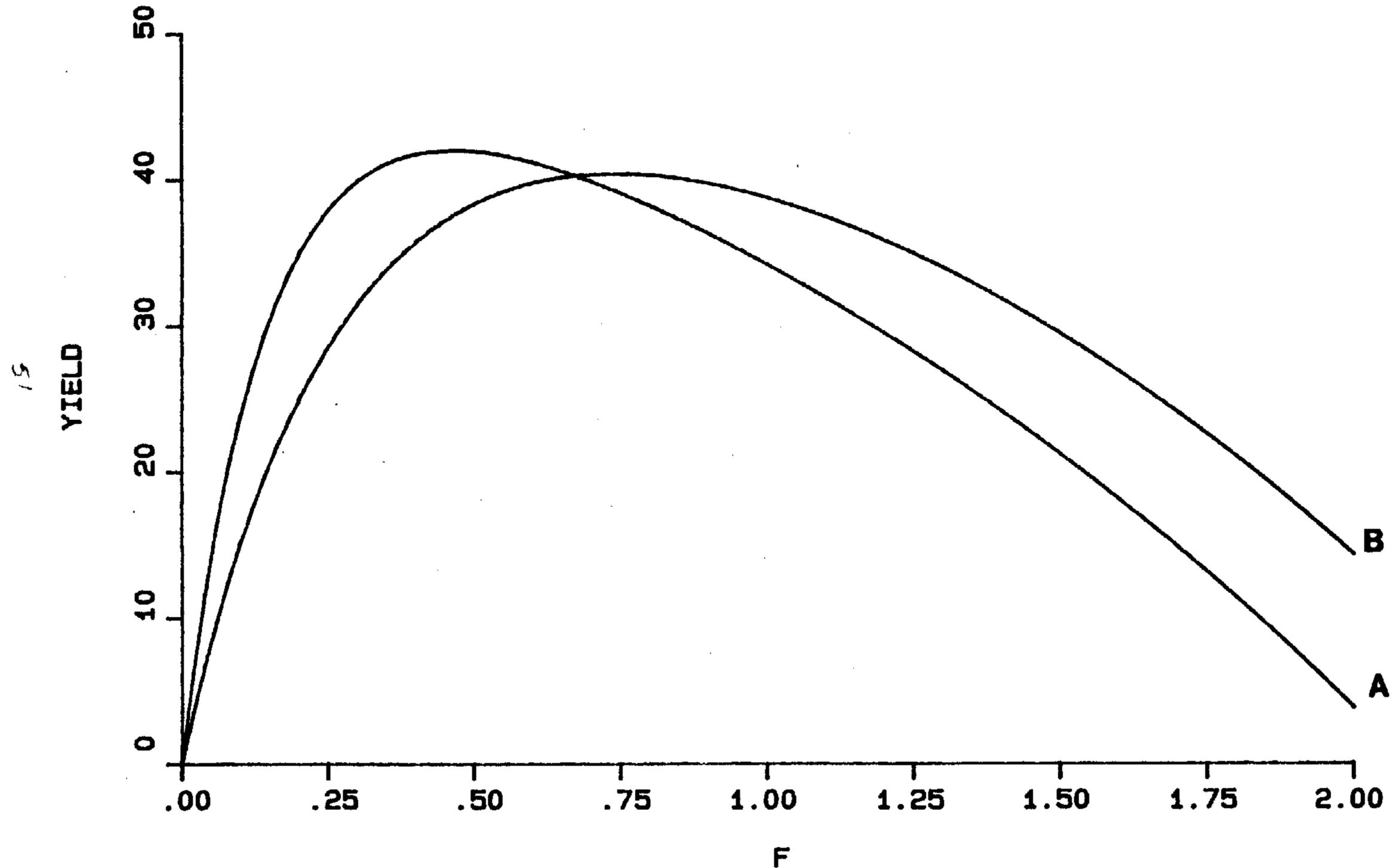
25. White shrimp stock-recruitment relationship between annual recruitment and August parent stock. A: replacement line with no fishing; B: replacement line at maximum sustainable recruitment.

WHITE SHRIMP



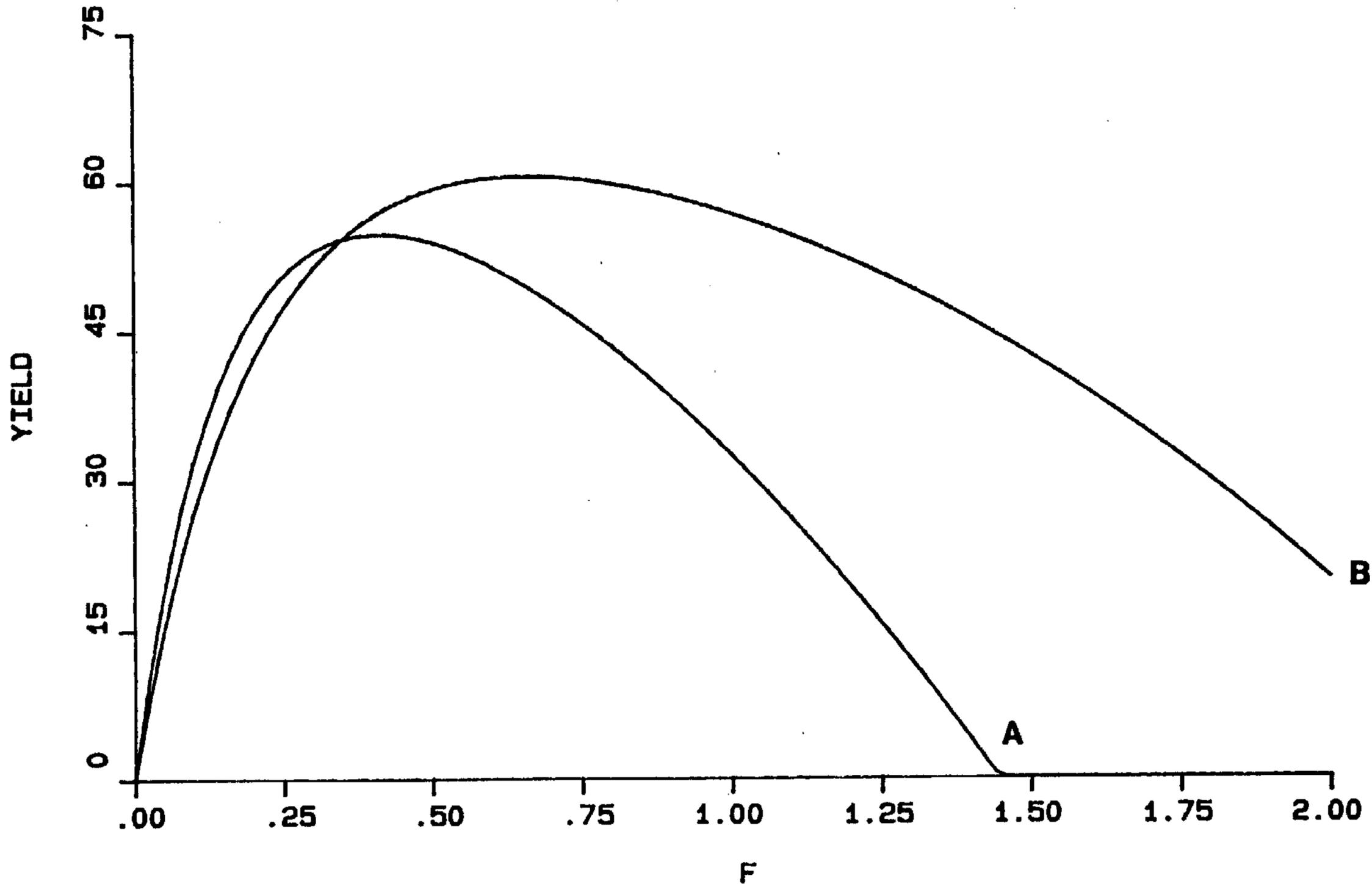
26. Projected yields for white shrimp assuming no stock recruitment relationship exists. Baseline fishing intensity = 1.0. A: yield curve for the present fishing pattern; B: yield curve with fishing on new recruits delayed until October.

WHITE SHRIMP



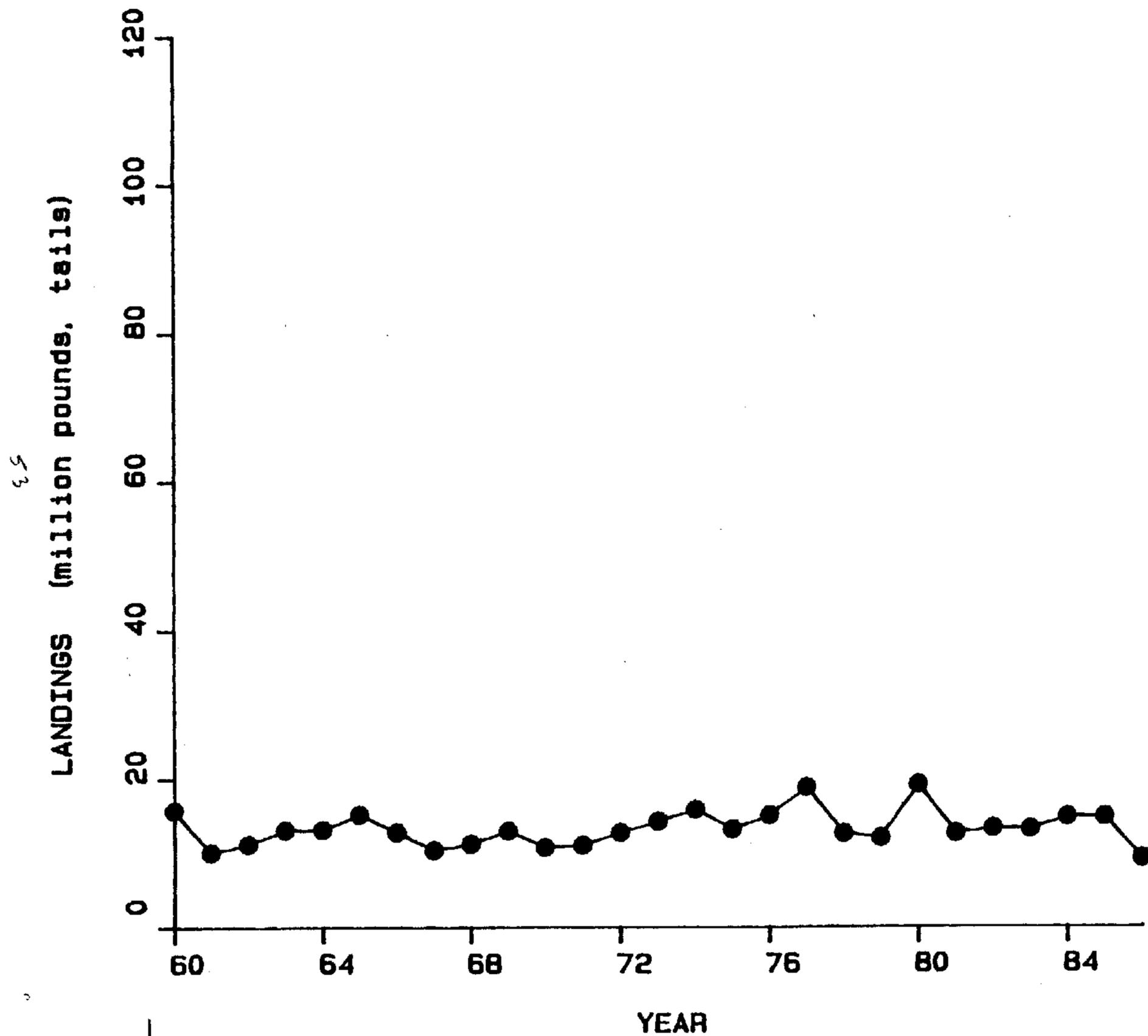
27. Projected yields for white shrimp assuming the April stock recruitment relationship holds. A: yield curve for the present fishing pattern; B: yield curve with fishing on new recruits delayed until November.

WHITE SHRIMP



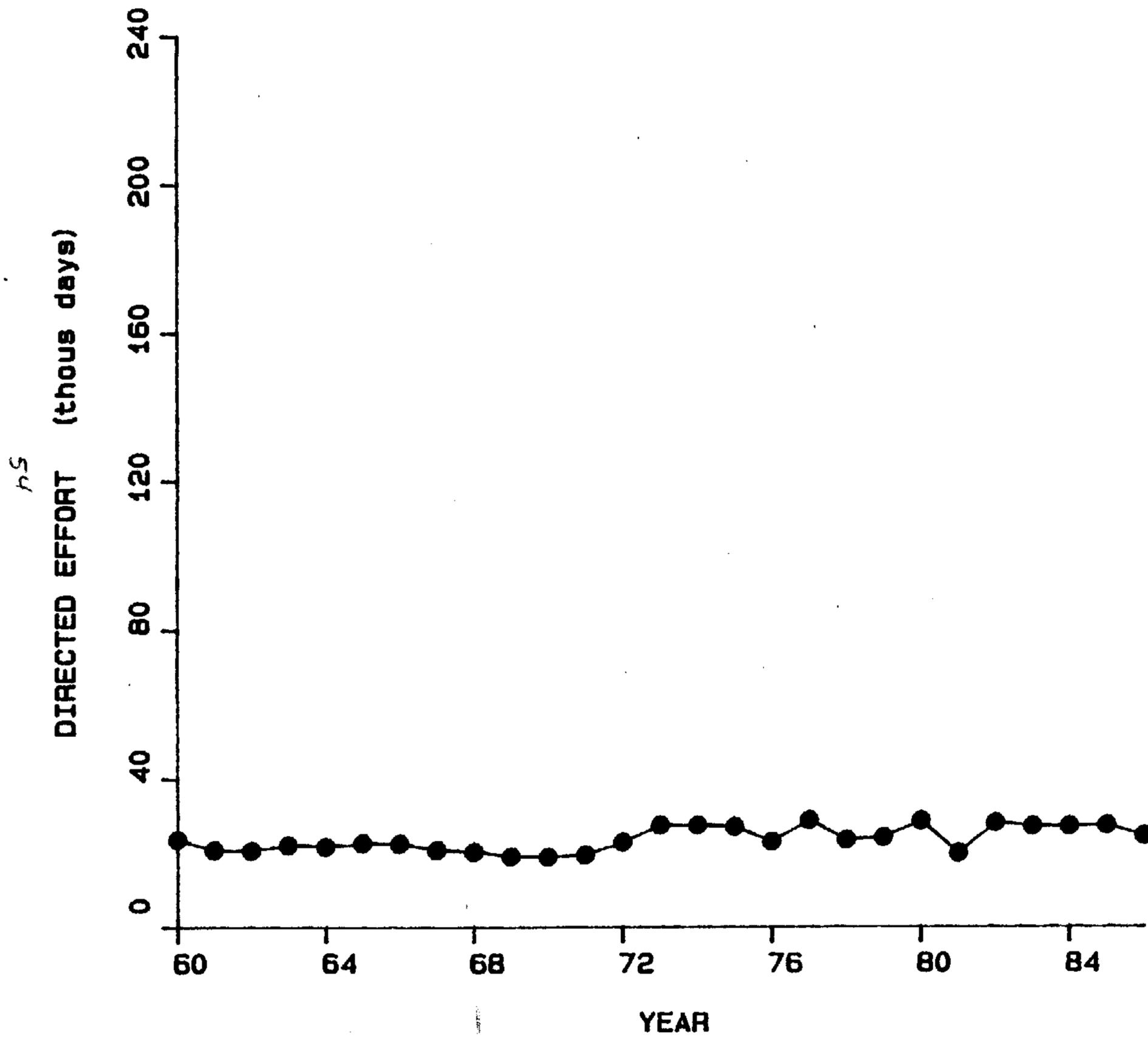
28. Projected yields for white shrimp assuming the August stock recruitment relationship holds. A: yield curve for the present fishing pattern; B: yield curve with fishing on new grounds.

PINK SHRIMP



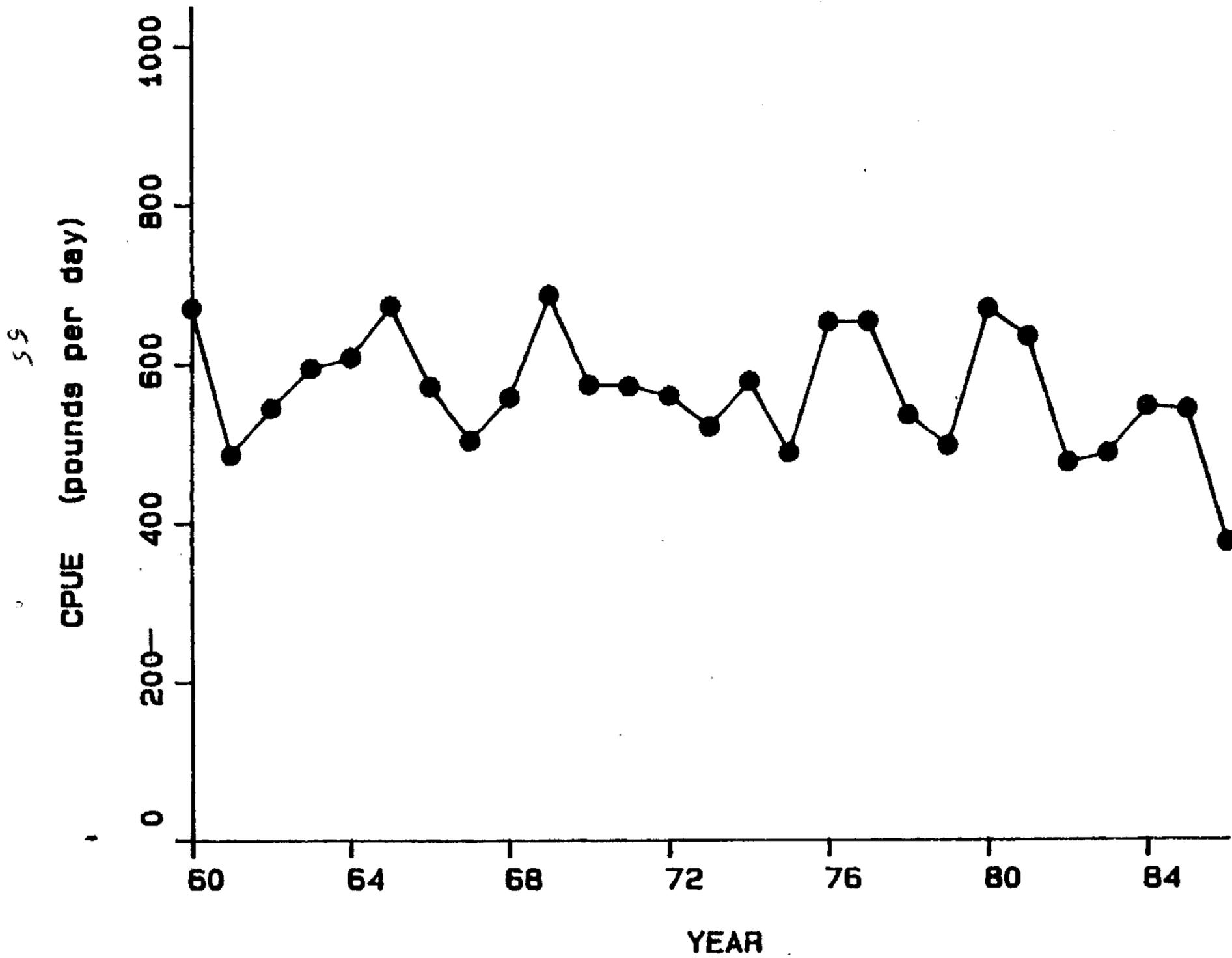
29. Reported annual landings for pink shrimp.

PINK SHRIMP



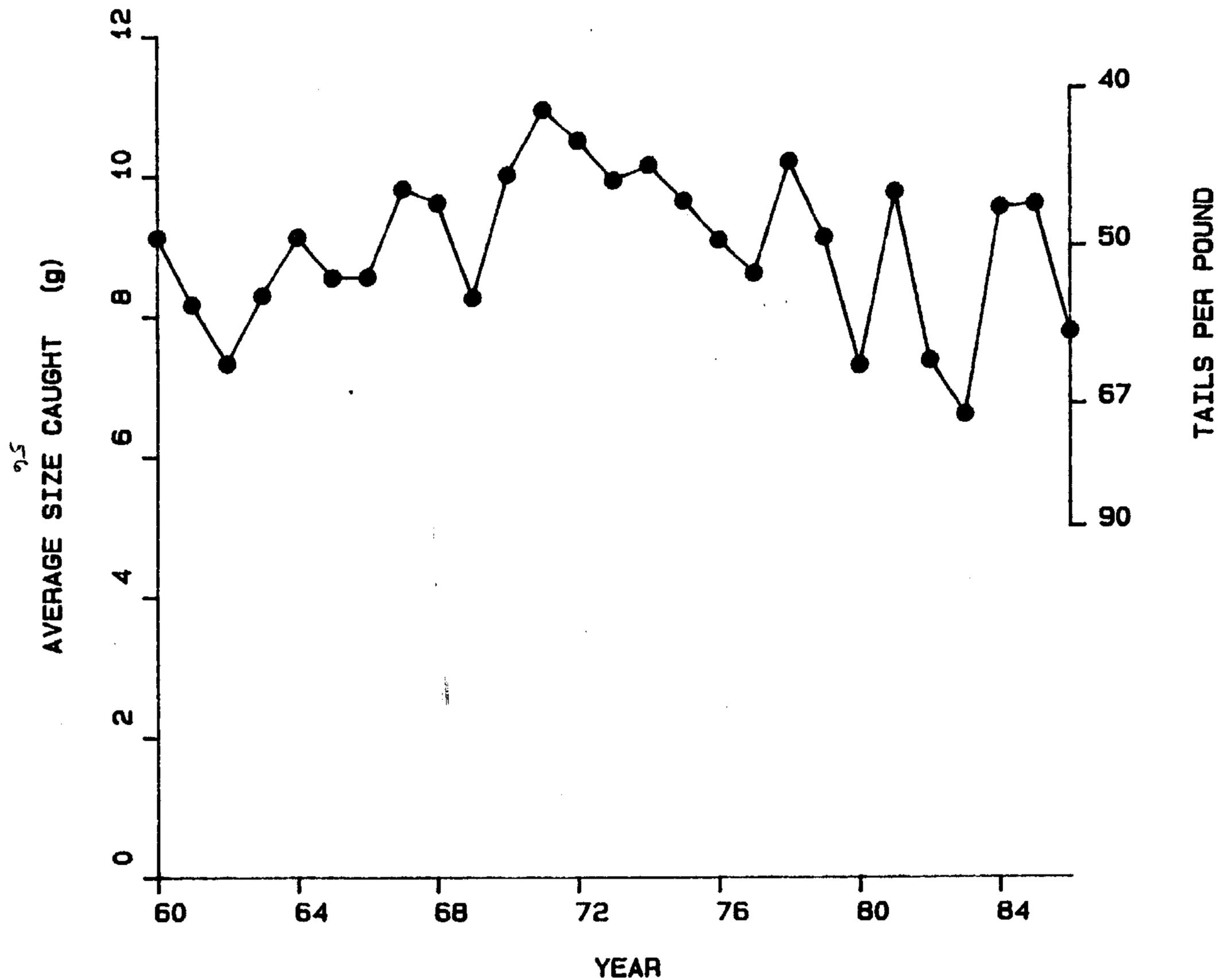
30. Estimated annual directed effort for pink shrimp.

PINK SHRIMP



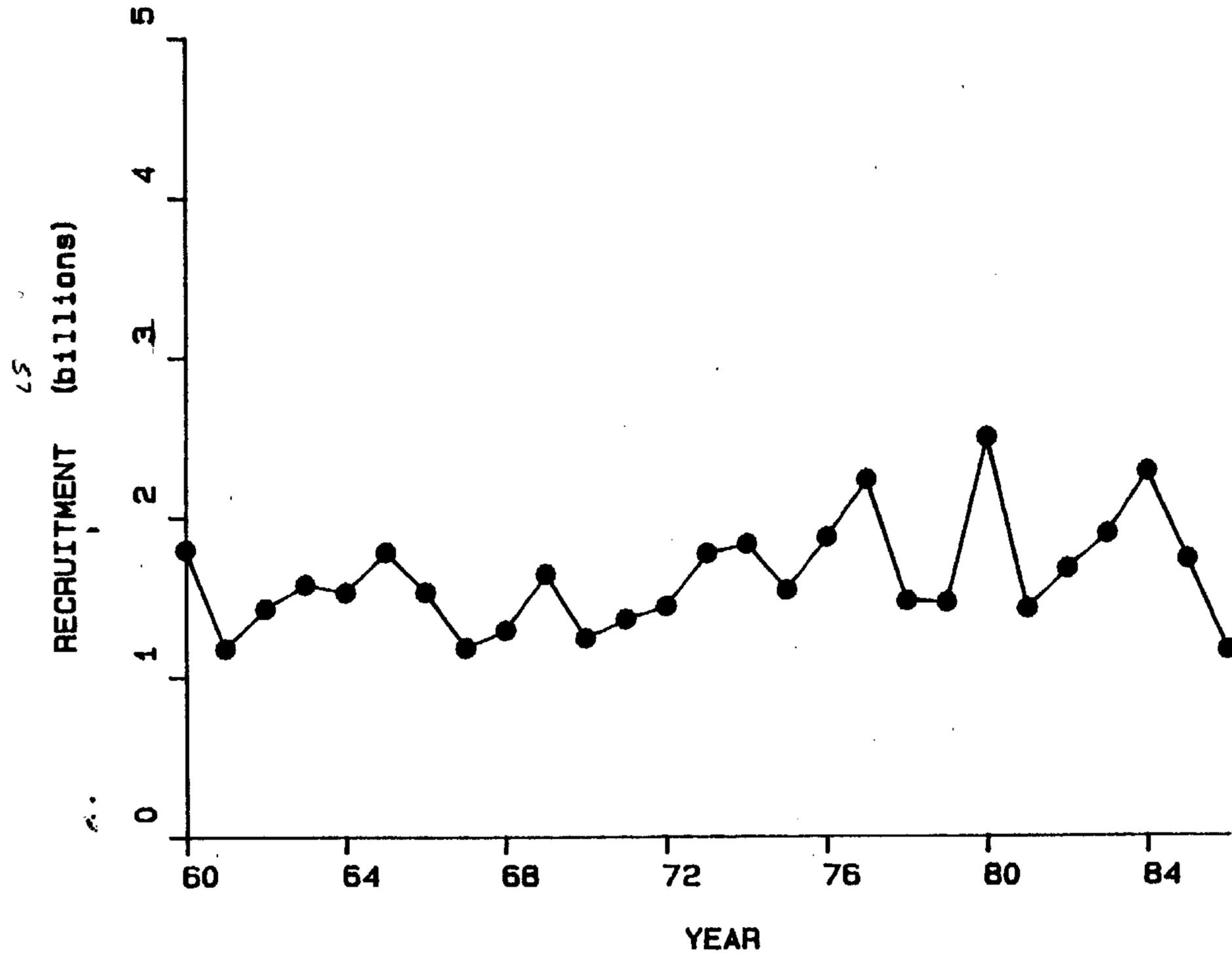
31. Estimated annual average catch per unit effort for pink shrimp.

PINK SHRIMP



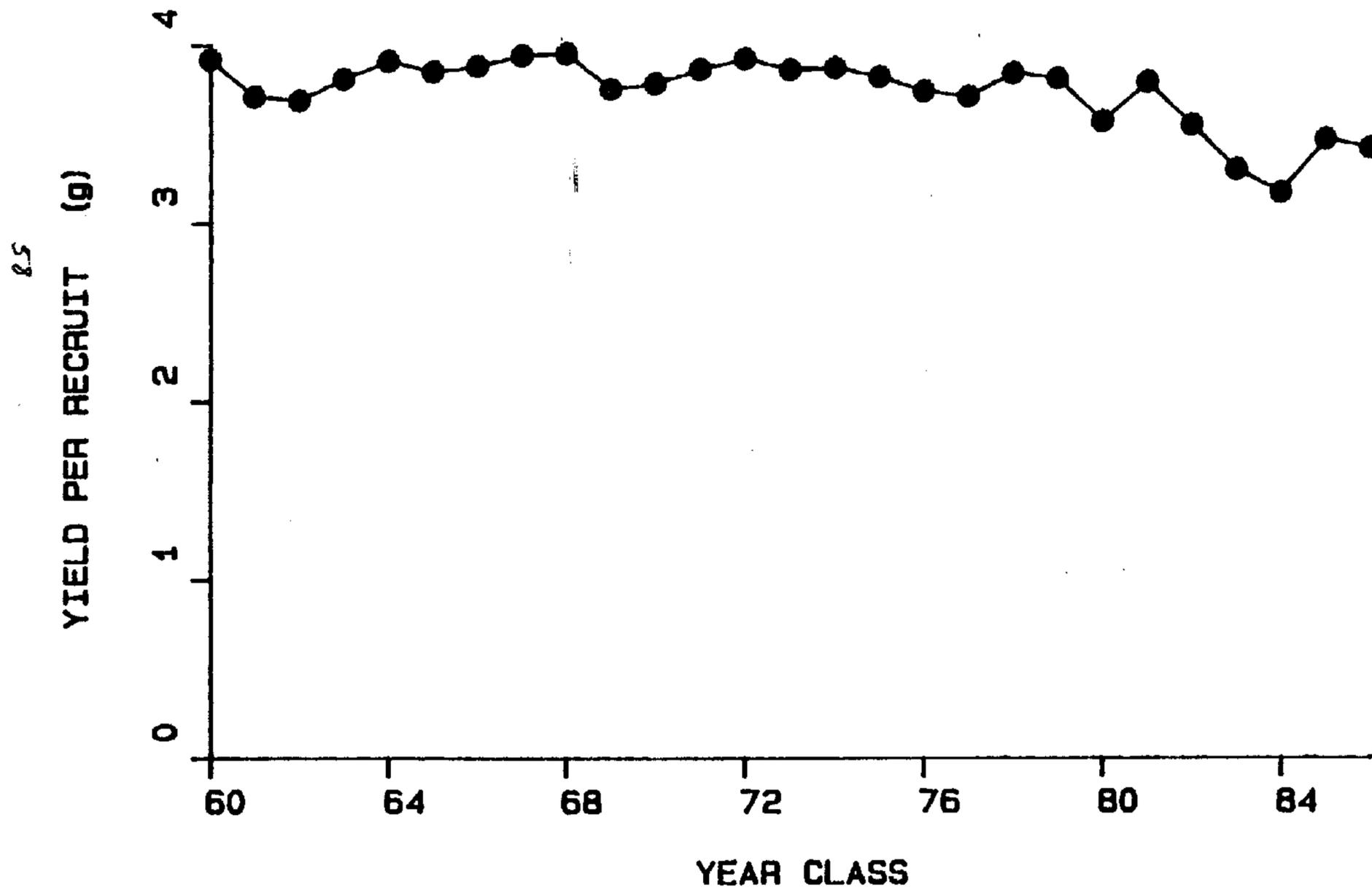
32. Annual average size of pink shrimp landed.

PINK SHRIMP



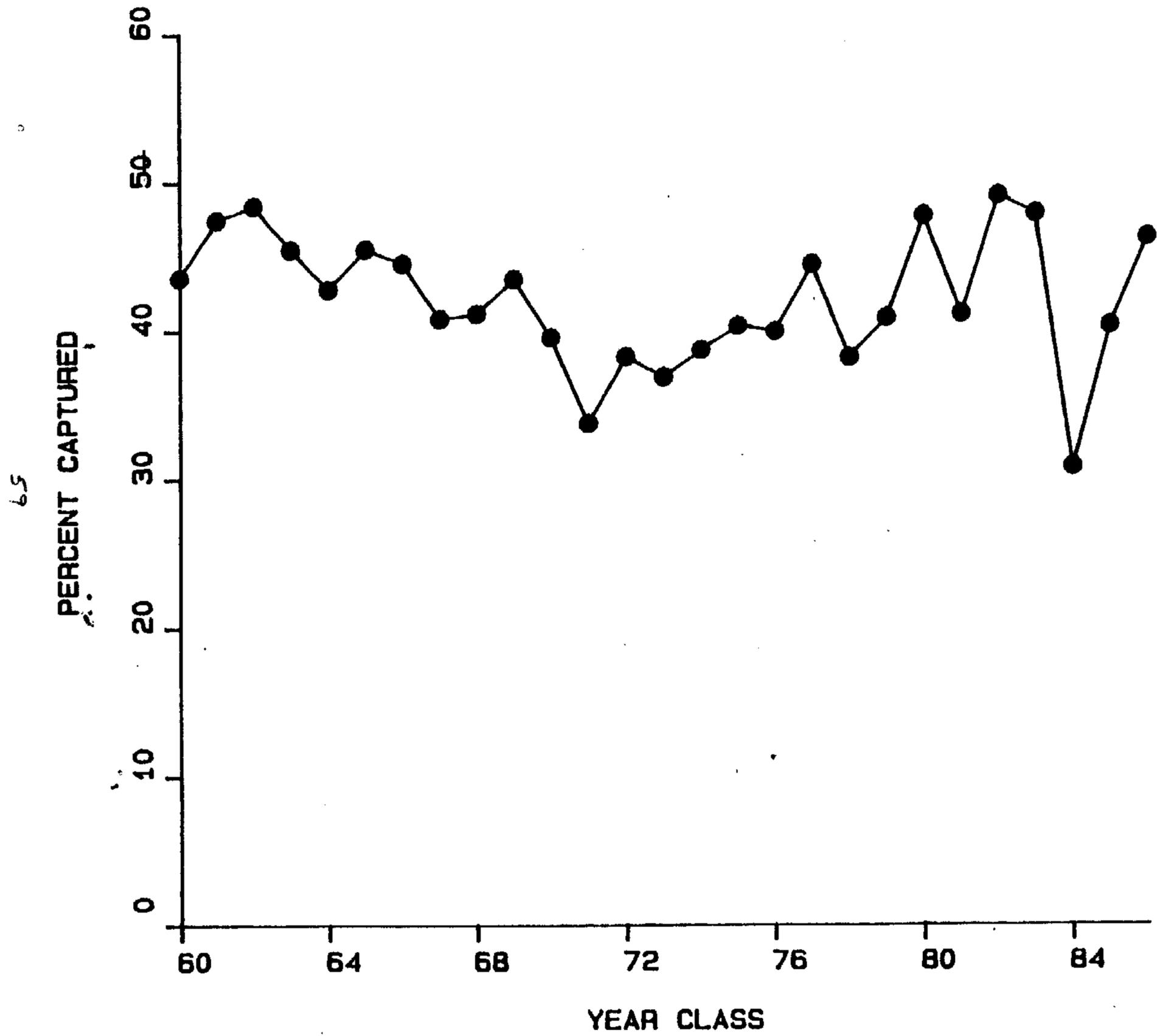
33. Annual average recruitment of pink shrimp.

PINK SHRIMP



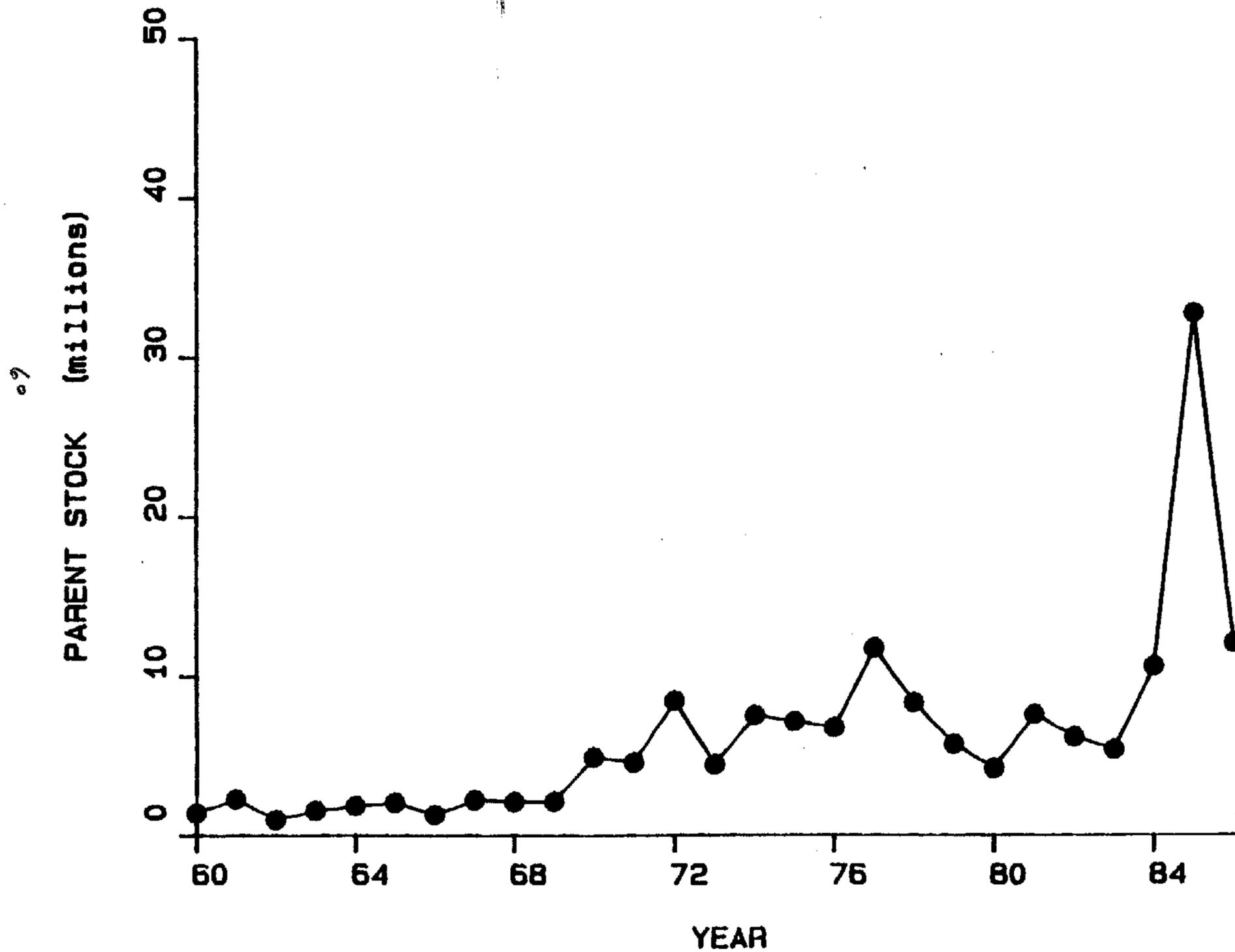
34. Estimated realized yield per recruit for each pink shrimp year-class.

PINK SHRIMP



35. Percentage of pink shrimp recruits captured by the fishery from each year-class.

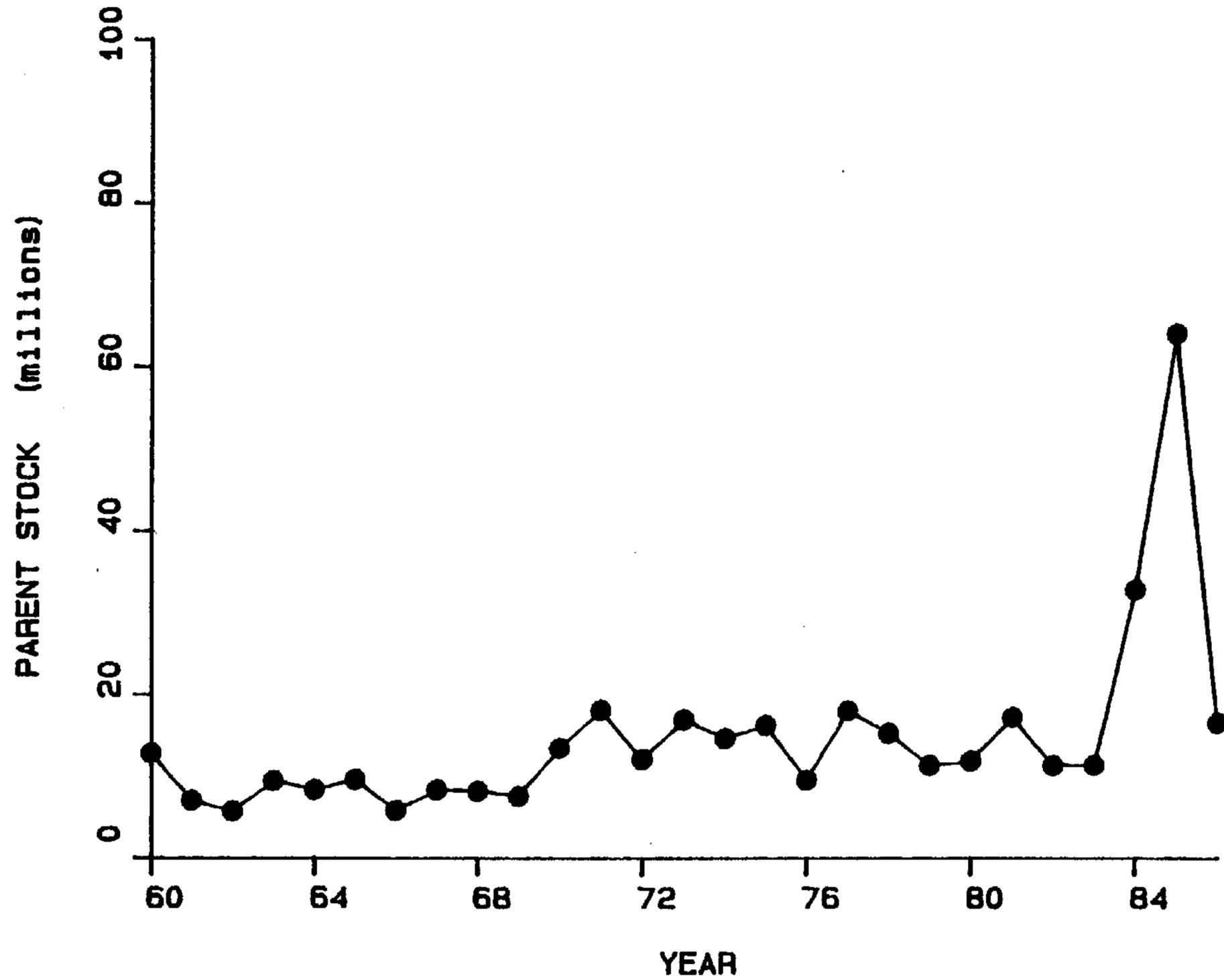
PINK SHRIMP



36. Estimated parent stock size (age 5+) for pink shrimp in July of each year.

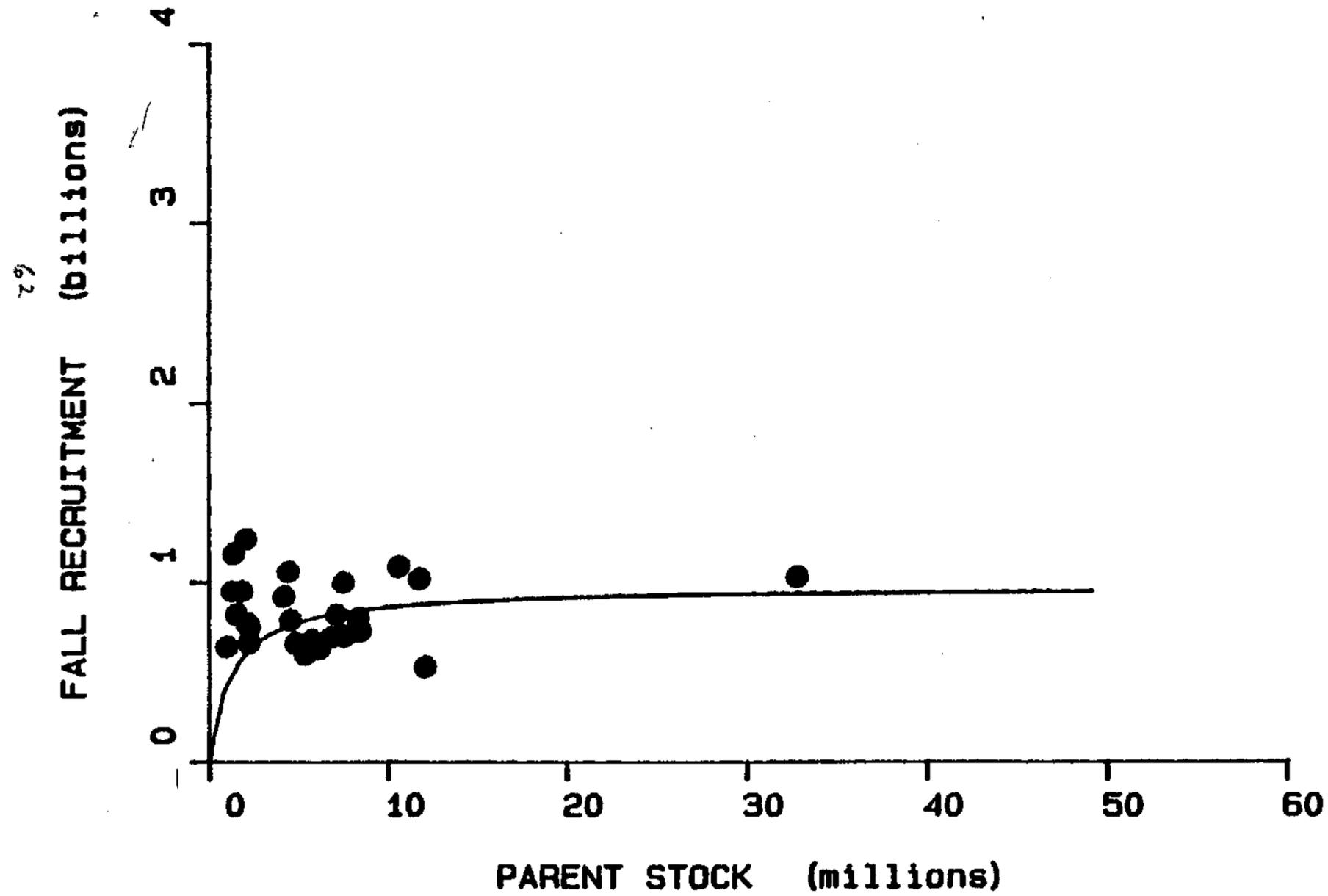
PINK SHRIMP

19



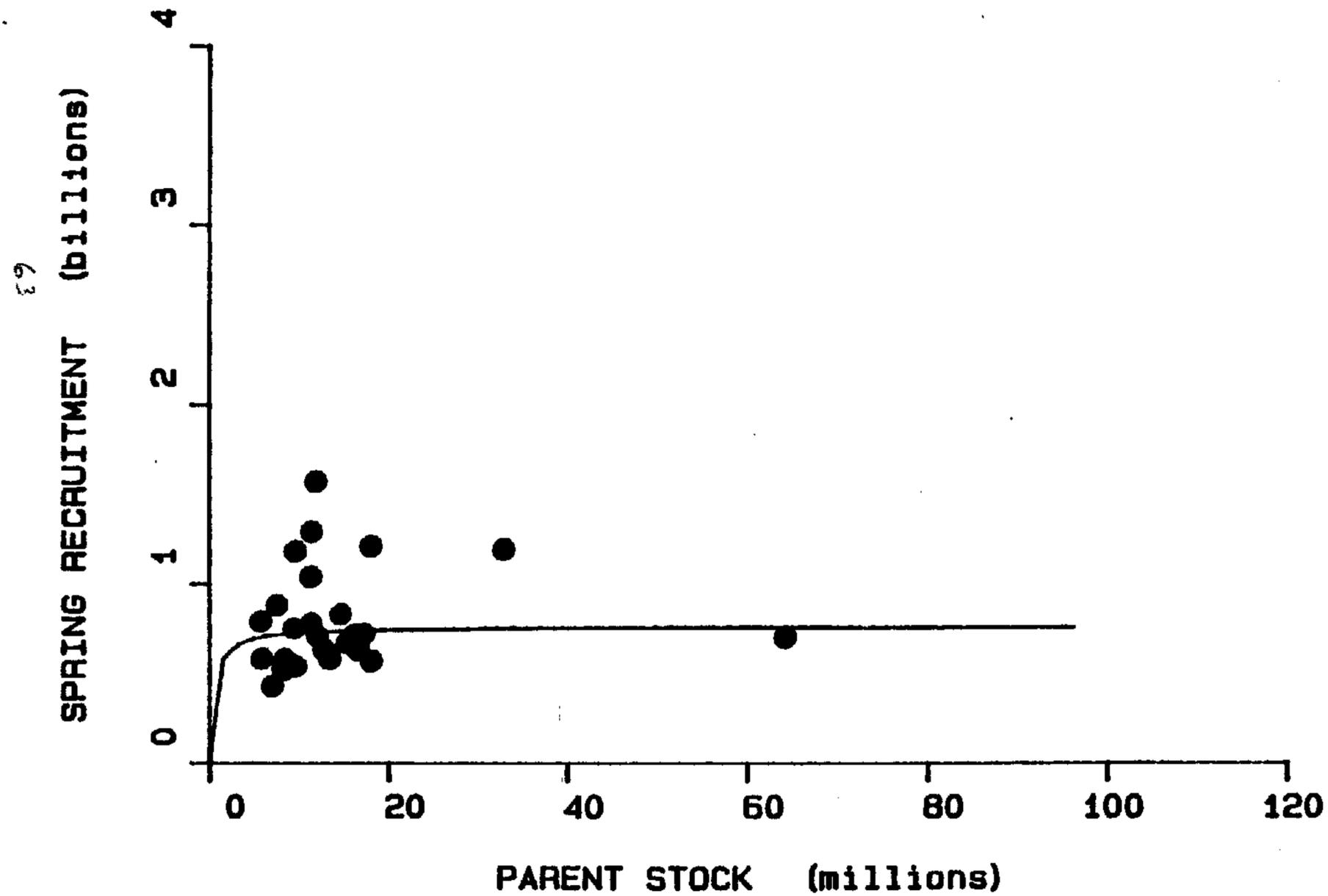
37. Estimated parent stock size (age 5+) for pink shrimp in January of each year.

PINK SHRIMP



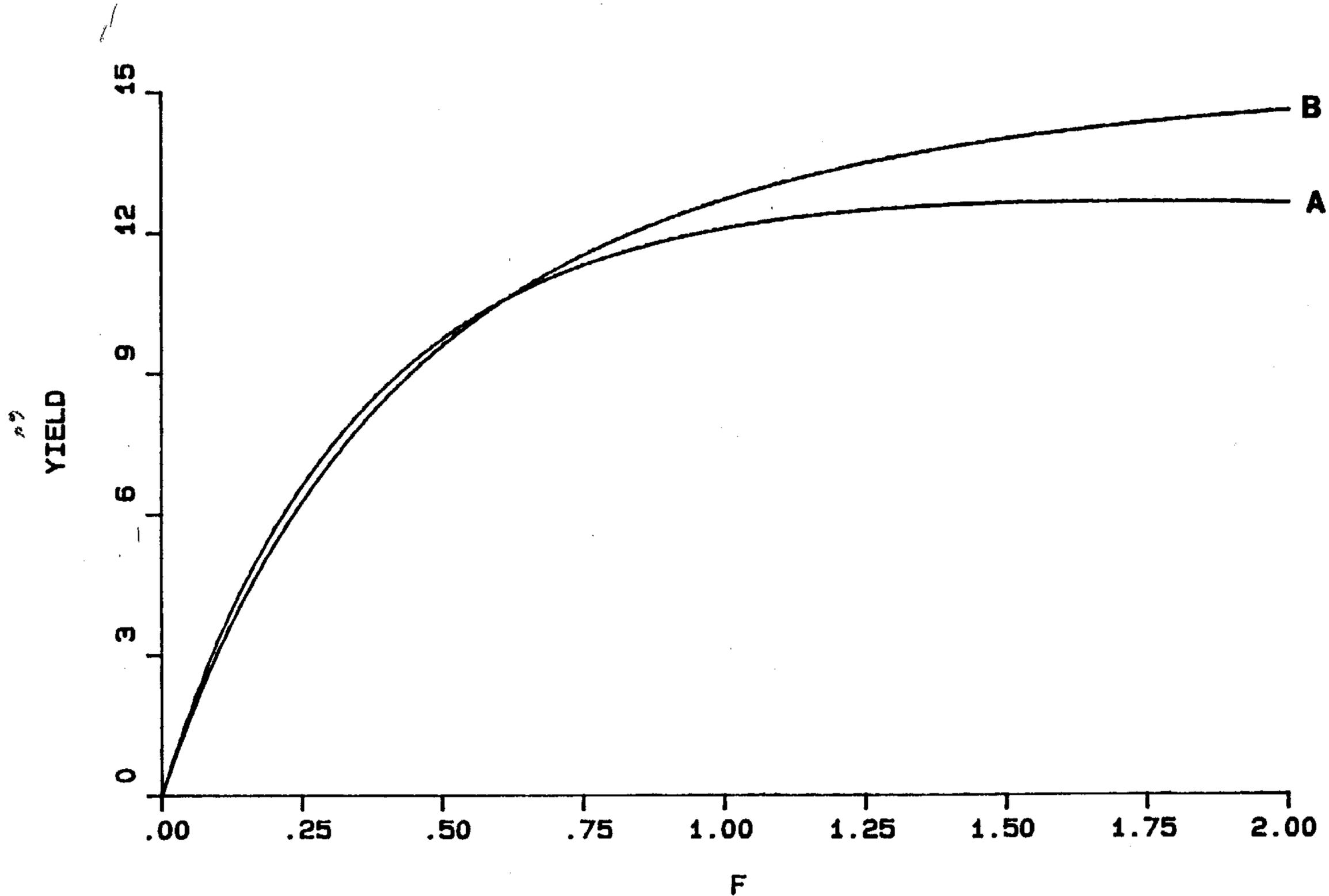
38. Pink shrimp stock-recruitment relationship between fall recruitment (July-December) and July parent stock.

PINK SHRIMP



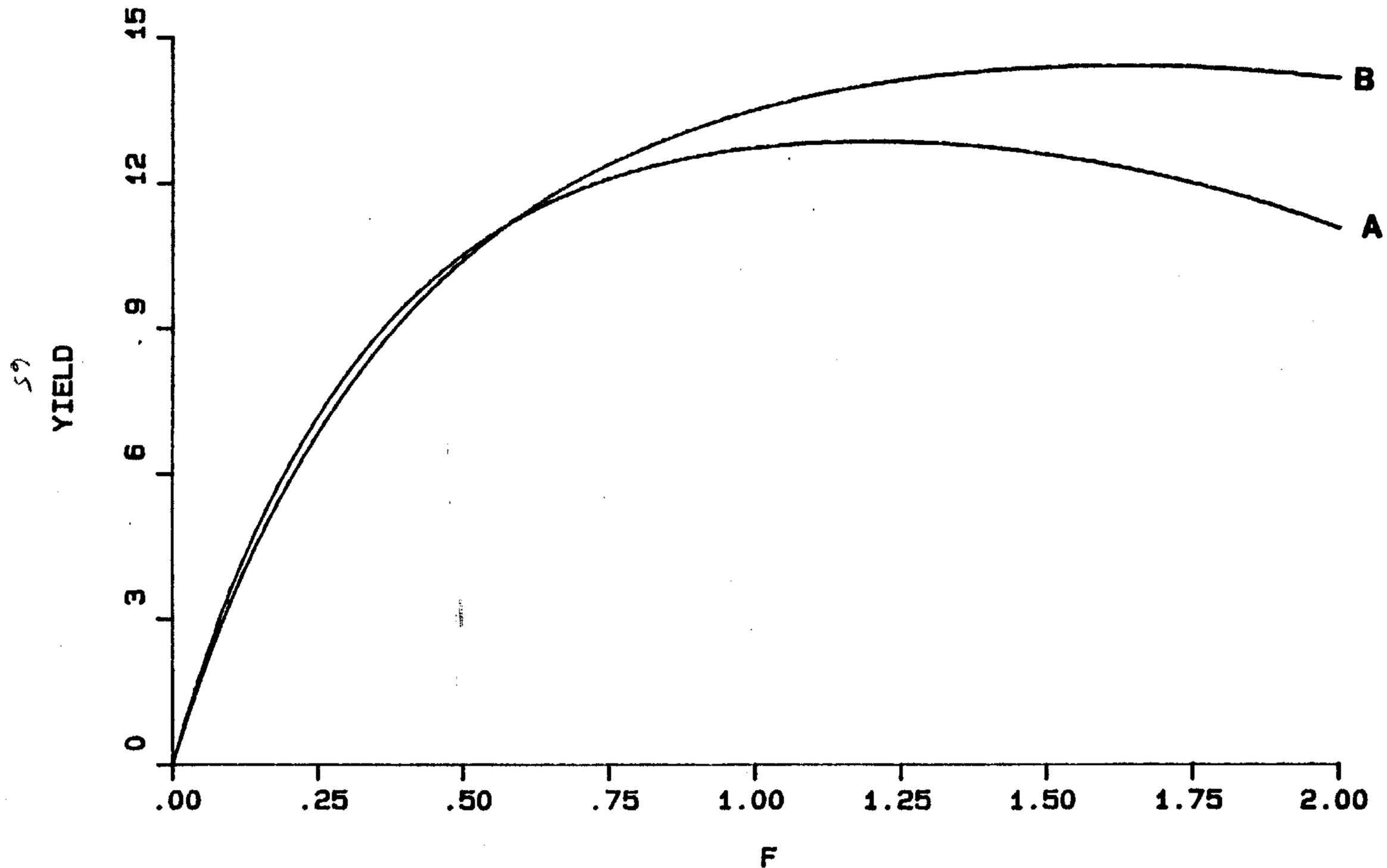
39. Pink shrimp stock-recruitment relationship between spring recruitment (January-June) and January parent stock.

PINK SHRIMP



40. Projected yields for pink shrimp, assuming no stock-recruitment relationship exists. Baseline fishing intensity = 1.0. A: yield curve for the present fishing pattern; B: yield curve with no fishing on new recruits for two months.

PINK SHRIMP



41. Projected yields for pink shrimp, assuming January/July stock-recruitment relationship holds. A: yield curve for the present fishing pattern; B: yield curve with no fishing